PROTECTION OF THE PUBLIC FROM

AERIAL ATTACK

An examination of the Present Proposals by a Group of

CAMBRIDGE SCIENTISTS

THE PROTECTION OF THE PUBLIC FROM AERIAL ATTACK

Being

A CRITICAL EXAMINATION OF THE RECOMMENDATIONS PUT FORWARD BY THE AIR RAID PRECAUTIONS DEPARTMENT OF THE HOME OFFICE

by

THE CAMBRIDGE SCIENTISTS' ANTI-WAR GROUP

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attacked with high explosive bombs, with incendiary bombs, or with all of them together. Is gas attack, then, the worst danger? According to officials of the Air Raids Precautions Department, the answer is "No."

> ". . . the chief danger to be anticipated in the event of an air-raid was from high explosive, the next in importance from incendiary bombs, and the third, but least in importance, from gas. . . ."
>
> Commander Franks, *Manchester Guardian*, 1.10.36.

Our only protection then is from the danger which is "least in importance." The following chapters will describe to what extent we are protected from this.

I

GAS-PROOF ROOMS

To MAKE a "gas-proof" room we are advised in A.R.P. Handbook No. 1, p. 28, as follows:

"The methods of protecting buildings or rooms against gas, that is to say, of making them as gas-tight as possible, are fairly simple. Reliance must not be placed on glass windows. If strong paper is pasted over the glass it will prevent collapse in case the glass is cracked. If the window has shutters, these should be closed. Otherwise, if planking is available, it is advisable to board up the windows on the outside, as an additional protection against the effects of high explosive. The inside of the window should be covered with materials such as oilcloth, linoleum, carpet or blanket. In cases where illumination is important translucent materials such as non-inflammable celluloid, or cellophane, may be used. These should be fastened round the edges of the window-frame by strips of wood or cardboard. Linen or cotton sheets, which have been backed by pasting strong paper on one side, will also prevent the penetration of gas.

"A blanket or covering of one of the suggested materials should also be fastened over the outside of the door-frame, leaving a flap which can be turned up to allow entrance (see Fig. 1). If there is a large crevice under the door, a thin strip of wood should be nailed to the floor to form a small step against which the door will fit tightly. The fireplace and any other opening through which air can enter will require to be closed by wood, cardboard or similar material. Even the keyhole should be stopped up. In many houses it will be found that the windows and doors are so ill-fitting that it is necessary to paste newspaper over the cracks to render them air-tight. A mush of newspapers and water is useful for stopping up large cracks."

The A.R.P's use of the phrase "gas-proof" tends to give rise to the conception of a room which is gas-tight, that is, which is isolated so that there is no exchange between the air inside and the air outside. In the Handbook No. 1, p. 65, we see:

> "In each house a room or rooms should be prepared to prevent the entry of gas, so that it may be safely occupied during a raid in which gas is used."

The possibility of preparing rooms which gas cannot enter, however, is the subject of profound differences of opinion, as the following quotations from two official sources show:

they worked held this high concentration for long. After an hour or so the concentration had fallen to 3 per cent or less and breathing was nearly normal. Measurements of the proportion of carbon dioxide in the room were made regularly for two and a half hours from the time of evaporating the "dry ice." In a similar way the time taken for the gas to leak out to half its original value was measured in four rooms—the basement of a shop, the dining-room of a semi-detached house, the sitting-room of a Council house and the bathroom of a modern villa. As stated above the leakage half-times for these rooms were $2\frac{1}{2}$, $2\frac{1}{2}$, $3\frac{1}{2}$ and $9\frac{1}{4}$ hours respectively. The reason for the last room being so much better than all the others is that it has steel-frame windows which were sealed with plasticine, painted and tiled walls, and a concrete floor covered with cork tiles.

A CRITICISM AND ITS ANSWER

In the experiments described a quantity of gas was liberated into a room and the time taken for some of it to leak away was measured. We thus obtained a figure for the "leakage half-time," a constant for the room which is defined on p. 18. We use this constant in calculating the time taken for a gas to enter the room from the outside. We have been asked whether our calculations are justified. Does a knowledge of the rate of leakage *from* a room enable us to determine the rate

of penetration of the same gas, or other gases *into* the room from the outside? DEPENDS ON WHERE OUTER WALLS ARE LOCATED!

In the first place let us assume that the carbon dioxide passes from the room (being replaced by air) by the process known as "diffusion." This process is analogous to that taking place when we drop a lump of sugar into a cup of tea and allow the tea-cup to stand quite still. After a considerable time the tea becomes uniformly sweet as the sugar molecules move (diffuse) "under their own power" upwards, from the place where they are present in greatest numbers, to the weaker solution at the top. In the case of the "gas-proofed" rooms the molecules of carbon dioxide may be pictured as passing from the room one by one through the minute pores in the plaster, the newspaper mush and the bricks, or along cracks in which the air is still. We know that the rate of such diffusion (the rate of leakage) would, under these circumstances, be controlled by the size of the gas molecules, the resistance offered by the pores of the wall, and the difference in concentration of the gas on the two sides of the wall—or the "concentration gradient." When the gas is thus diffusing out of a room into a large open space, diffusion will go on until practically all the gas in the room has disappeared. The rate of leakage will decrease as the concentration inside the room falls away. When the same gas is diffusing into the room, diffusion will go on until the concentrations inside and outside the room are the same. And it is true that the

rate of diffusion inwards will be slightly less than that outwards, for the carbon dioxide entering the room increases the internal concentration more and more as time goes on.

But a leakage of carbon dioxide from a "gas-proof" room is not primarily a process of diffusion, but almost entirely one of "mass flow." In the analogy taken above, it is as though we stirred the tea, so creating water currents which carry the molecules of sugar rapidly about the cup in groups, so that uniform sweetness is rapidly attained. By far the greater part of the carbon dioxide passes from a room (and poison gas into a room) in little streams of air blowing to and fro in the small holes and tiny cracks in the plaster, bricks, doors, etc. These air streams are due to variations in outside air pressure associated with winds (see p. 103). Similarly, poison gas would enter the room in bulk, not molecule by molecule.

The statement that leakage is due to "mass flow" is based on

(*a*) the rapidity of leakage;

(*b*) the results obtained in experiments with the blower (p. 101);

(*c*) published papers dealing with the porosity of bricks and plaster to carbon dioxide.[1]

[1] E. Madgwick, *Philosophical Magazine*, 12.1160.1931: "Taking 15 cm. of water as wind pressure, the rate of flow through 9 inch (brick) wall covered with 1 inch plaster sized, papered and distempered is ·0084 cubic metres per square metre per hour. Considering only the resistance of the brick it is ·115 cubic metres per square metre per hour."

on the outskirts of a city should help in the work of evacuation was made by the Chairman of the Barnet Urban District Council. This suggestion was promptly repudiated by Wing-Commander Hodsall, who said:

> "The principle of the policy of the Air Raid Precautions Department is to clear everybody off the streets and get them under cover during an air raid."
>
> (*Manchester Guardian*, 4.9.36.)

Commander Franks tells us more about this cardinal principle:

> "The citizens would find the best shelter in their own homes, and in the unfortunate event of an air raid, all those who found themselves within five minutes walk of their homes would be advised to make their way home as quickly as possible.
>
> "For those who found themselves in the streets, a number of buildings to be selected by the Local Authority would be available as public shelters, but in them there would be no safer accommodation than anyone would find at home. The idea that people could rush from their homes and find some safer shelter elsewhere was a completely illusory one and could only lead to panic . . . panic caused through ignorance was to be dreaded more than anything else."
>
> (Commander Franks, at Manchester. *Manchester Guardian*, 1.10.36.)

THE ANATOMY OF PANIC

Fear of panic is the dominant note of all speeches of Air Raid Precautions officials. Seldom do they fail

to mention that panic is the greatest danger which they fear.

Why should they fear panic so much? Are they so much obsessed by fears of what may happen to women and children in a frightened mob, that the danger from high explosive bombs seems small by comparison? Let an official of the Red Cross Society provide an answer:

> "In the next war, an aggressor will try to create such a state of panic amongst the civil population as to arouse a craving for peace. That panic can be avoided if every man and woman knows what to do in case of air raids."
>
> (Sir William Coates, Member of the Council of the Red Cross Society. *Manchester Guardian*, 2.10.36.)

—a statement strangely recalling the dictum of the French General Pouderoux, who said:

> "The aim of aerial attack is to induce the population to compel their governments to sue for peace."

A population which "compels their government to sue for peace" would be, from the government's point of view, in a state of panic. This is the panic which "was to be dreaded more than anything else." This is the panic which it is the main object of Air Raid Precautions to avoid. Air Raid Precautions are an essential part of war preparations; they are a part of those preparations in which the acquiescence of the people is vitally essential. ⟹ POLITICS!!!

Firstly, there are the true gases or vapours, such as chlorine, phosgene and prussic acid gas. All of these are choking gases, which are used to cause dangerous casualties or death. During the war, they were used extensively in trench warfare, as large quantities could easily be released from cylinders and allowed to drift with the wind in the desired direction. This property of drifting with the wind is of some importance, for it means that the gas will not remain for long periods in any one place except on still days.

If gas-tight rooms were available, there would usually be no danger to the civil population from this source, but we believe that we have shown that the "gas-proof" room is not gas-tight.

Now it may be objected that, although the "gas-proof" room is not hermetically sealed, it will nevertheless protect the occupants for the two or three hours necessary in case of an attack by a choking gas. It is useful therefore to consider the actual length of time for which it would in fact give protection. If the reader will turn to p. 109 he will find an analysis of experiments with phosgene carried out by Dr. Hermann Engelhard. IGNORES % KILLED IN HAMBURG!

It will be seen that with 20 tons of phosgene, a lethal concentration was set up at a distance of two or three miles. (See Table p. 127 for concentrations of different gases required to cause dangerous injury.) At 1,000 yards, the concentration would be enough to kill anyone exposed for more than a few minutes to the

FALSE: VERY LOW LETHALITY!

gas. Now on p. 116 is given a table showing the time for which occupants of "gas-proof" rooms may hope to live—or, more accurately, the time taken before they are killed—during a gas attack. Consider the example emphasised in the table. Here we have assumed a concentration of gas outside, which, while at first high enough to kill an unprotected man in 6 minutes, is falling rapidly owing to the effects of wind. We assume that the gas blows away so quickly that every 10 minutes its concentration is halved. In Engelhard's experiments it took 10 minutes to liberate the gas from its cylinders, so that this assumption is reasonable. Then a person occupying a good "gas-proof" room, the leakage half-time of which (defined on p. 18) is 3 hours, would have breathed a lethal dose of phosgene in 2 hours. Therefore, if 20 tons of phosgene be released along a line three-fifths of a mile long, all the occupants of the "gas-proofed" rooms within an area 3 miles long and three-fifths of a mile wide will receive a fatal dose in 2 hours. It is evident, then, that these people will need a second line of defence, even if they obey the Home Office advice to stay at home. ASSUMES CYLINDERS, NOT BOMBS!

In general, the true gases mentioned above affect only the eyes and lungs. A suitable mask will therefore afford complete protection for the time that the filter lasts. This length of time is discussed below.

Secondly, there are the vesicant or blistering liquids, such as mustard gas and Lewisite. Such liquids or

IRRELEVANT TO BOMBS: EXAGGERATES DURATION!

into sealed perambulators, boxes, or bags, are merely ignorant. Young babies who normally sleep from one feed to the next—perhaps three and a half hours—are unlikely to do so in a stuffy, damp atmosphere. The number of young babies, who after an interval, are normally picked up clean and dry (particularly if they have been screaming) is small. The possibility of young babies being seriously damaged, psychologically as well as physically, by such treatment is not to be lightly dismissed—quite apart from any damage that may be caused by poison gases. Changing the baby's napkin, keeping him just comfortably warm, providing him with suitable food at regular intervals—all of these services become impossible, and the results can only be disastrous. With older children, toddlers for example, the difficulties are still more obvious. At an age when any frustration is liable to lead to screaming and tantrums, the effect on the child of being shut up in a very confined space for hours on end can be imagined. The problem facing the parents who possess a number of small children, each of whom needs to be kept in a box supplied with pumped air, may well prove insuperable.

Major Blackmore says little can be done for the child under five. Even if complete protection against gas was offered to adults, does he suppose that mothers and fathers would protect themselves and watch their children suffocate before their eyes?

IV

INCENDIARY BOMBS

EXPERTS on the tactics of bombing appear to hold the opinion that their respective air forces, when engaged in attacking a town, will employ, for the purpose of demoralising the civil population, a combination of gas and incendiary bombs, accompanied probably by the lighter type of high explosive bomb, and by the shrapnel bomb. The heavier high explosive bombs can only be carried by aircraft in relatively small numbers, and will therefore be employed only against strategic points—railways, electric power stations, arsenals, etc. By far the greatest demoralising effect on a civil population can be produced by a combination of gas and incendiary attack. On hearing the air-raid warning people will rush to their "gas-proof" rooms and then, when the incendiary bombs set fire to the upper parts of their dwellings, they will either run out and be caught by gas, or stay inside and be roasted alive under the burning house. This is how they would act if they followed the instructions of the

Home Office. As, however, our experiments on the "gas-proof" room illustrate quite clearly that the ordinary dwelling-house is quite incapable of affording protection, it probably will not matter much what a civil population does under a gas and incendiary attack. Nor is it profitable to argue whether the gas or incendiary bomb is the more devastating, as it is necessary to contemplate an air attack in which both will be employed, with a sprinkling of high explosive bombs, which will considerably heighten the "psychological effect." This is the type of attack which people in large towns must expect if war breaks out; our task in this section is to discuss the proposals of the Home Office for dealing with incendiary bombs, remembering that whoever deals with them will require, almost certainly, simultaneous protection against gas. PROVED WRONG!

The purpose of the incendiary bomb, which is filled with thermite, is to start a fire; in order to know how to provide protection against such fires it is necessary to understand how the incendiary bomb works. Ordinarily no substance can burn except in air. Thermite, however, can burn independently of air; that is to say thermite cannot be extinguished merely by cutting off the air supply, and is unaffected by ordinary fire extinguishers.

Thermite is a mixture of aluminium and iron oxide and can be bought from chemical manufacturers for about two shillings a pound. It can be most easily ignited by means of photographic flash powder; the

PROPAGANDA

extreme lightness and cheapness of the incendiary bomb must be borne in mind. Mr. Noel-Baker cites the case of a single aeroplane carrying a load of less than a ton of bombs which succeeded in starting three hundred fires, and if we take a specimen raid of nine bombers, each carrying a thousand "kilo" bombs, nine thousand of these could be dropped on an area of two square miles. If very generous allowances are made for failures to function and for bombs falling on non-inflammable sites, in an urban area one fifth at least of these bombs should cause fires. This makes one thousand eight hundred fires. The danger of fire spreading over several blocks of buildings as in the San Francisco (1906) and Tokyo (1933) earthquakes, making the centre of the conflagration quite unapproachable by fire brigades is obvious.

To summarise this section, we reach the conclusion:

(*a*) That for individuals the cost of making buildings impenetrable to incendiary bombs is prohibitive.

(*b*) That, bearing in mind the probability of combined incendiary and gas attack, the civilian population will have considerable difficulty in extinguishing fires caused by incendiary bombs in private houses, unless assisted by experts. ← WRONG!

(*c*) That the fires caused by a raid such as is outlined above would very likely be impossible to deal with, even with the improved fire brigade organisation envisaged by the Home Office, because of the probable amalgamation of separate outbreaks into a vast conflagration.

The difficulties likely to be caused by inadequacy or actual breakdown of water supply, obstruction of roads by explosions and collapse of buildings, and disorganisation of activity by poison gas may also prove overwhelming.

V

SUMMARY OF PART I

WE SHALL HERE SUMMARISE the results of Part I and add some general conclusions. The full experimental details and more detailed summaries are given in Part II.

I. EXPERIMENTS WITH "GAS-PROOF" ROOMS

"Gas-proof" rooms were prepared according to the instruction given by the A.R.P. Handbook No. 1; they were tested by three different methods and the results show that, assuming that the air outside contains enough mustard gas to kill a man in an hour, it would be possible on an average to remain alive for about three hours in the "gas-proof" room; in other words the "gas-proof" room is not gas-tight. Completely gas-tight rooms can only be constructed, at great expense, by experts.

Emphasis has been laid on the fact that, first, one million of the population do not possess a room which can be set aside for gas-proofing and that, secondly, seven millions more would have to live under conditions which are officially defined as overcrowded if

one of their rooms were set aside as a "gas-proof" room.

2. EXPERIMENTS ON GAS-MASKS

The types of gas-mask and their resistance to various kinds of poison gas are described. Experiments on a civilian type of mask, sold at 17*s.* 6*d.*, showed that a person wearing the mask would be protected against a probable concentration of chlorine for some hours. However, it is pointed out that gas-masks only protect the face and lungs, and therefore offer limited protection against mustard gas, which attacks the whole surface of the body.

3. INCENDIARY BOMBS

The present fire brigade system would not be adequate to deal with the hundreds of fires which would result from an air raid in which thermite bombs were used. Such incendiary bombs, and some simple experiments with thermite, have been described. It is shown that in the event of a combined gas and thermite attack (which might be expected in time of war) it would be practically impossible to put into practice the precautions recommended by the Home Office.

4. THE PROTECTION OF CHILDREN

Up to the present time, adequate methods for the protection of children under the age of five have not been proposed by the Home Office; the difficulties are pointed out.

VI

DISCUSSION OF PART I

THE HOME OFFICE, in its handbooks on Air Raid Precautions, made many specific recommendations for the protection of the civilian population, but it did not present, either in these handbooks or elsewhere, the experiments on which these recommendations were based. Experiments bearing on this problem are described in this booklet; and we believe that they afford proof of the inadequacy of the proposals of the Home Office.

Since the facts about these proposals must surely be known to the Home Office, we are at a loss to understand why they have been put forward. It is clear that the Home Office lays itself open to very serious criticism on a number of counts. While in some cases, such as the design of aeroplanes, guns, etc., secrecy on the part of the Government is in the national interest, it is by no means obvious that this secrecy should be extended to gas-masks. We have shown that one type of mask is efficient against chlorine; we have not extended our work to the more dangerous poison gases and arsenical smokes, but we think that the Home

Office should produce sufficient detailed information to satisfy us that the thirty million gas-masks that are intended for the civilian population are really efficient for all the gases likely to be used.

We learn from *The Lancet* of December 19th, 1936, that the Home Office has carried out some experiments to test the recommendations for "gas-proofing" rooms. Major Blackmore, replying to a doctor who asked for more information about the research behind the recommendations, stated that ". . . the experiments conducted had been performed on discarded telephone kiosks. . . ." We find it difficult to believe that these are the only experiments officially carried out, because a telephone booth is scarcely comparable with a room in an ordinary house. There is no doubt but that some of our results are a challenge to people in high places who have made certain categorical statements on behalf of the Government. We hope this challenge will not be ignored.

EXPERIMENTS USING CARBON DIOXIDE

Experiment I

The Peace Room, 15 King's Parade, Cambridge
November 1936

The Room

The room used in this series of experiments is in a basement with its ceiling at ground level. It is lighted by a window which, being below street level, is set in a well (6 feet deep, 2 feet wide, and as broad as the window). The only door in the room is in the wall opposite the window and opens into a narrow passage. The volume of the room was 60 cubic metres.

Preparation

The room was prepared exactly according to the method described in A.R.P. Handbook No. 1, p. 28. The gas fire was removed and the entrance to the chimney blocked with plywood which was held in place by several layers of sticky paper. The window frame was filled with a mush of boiled newspapers and water, small cracks in the window were pasted over

with two thicknesses of brown paper and a recess in the corner with three-ply wood and sticky paper, sealed with newspaper mush. A water-pressure gauge was fixed through the keyhole with plasticine. Any places where pipes penetrated the walls were sealed with newspaper mush. As the room is in the basement and there is a parquet floor laid on concrete, little gas could escape through the floor. There are no ventilators or air-bricks.

Method

Before sealing the door, several pounds of solid carbon dioxide were broken into small pieces and laid on the floor; the carbon dioxide was heated by an electric fire and the air over it was stirred by an electric fan. After about half an hour, during which time the door was sealed, the carbon dioxide had all sublimed. Fifty-five minutes after sealing the door the first sample of the gas in the room was collected. Samples were obtained through a glass tube which was sealed into the room with plasticine. These samples were collected in evacuated bulbs fitted with stopcocks; the bulb was attached to the tube in the door, and the stopcock opened to draw off the sample. When samples were not being collected the tube was sealed. The samples were kept in the bulbs for about a fortnight, during which time the Group made a Haldane gas-analysis apparatus. (For a description of this apparatus and its method of working see *Methods of Gas Analysis*, by J. S. Haldane

and J. Ivor Graham, London, 1935, p. 63.) Samples Nos. 6, 7, 1 and 2 were analysed by one worker and the rest by another. Both checked Nos. 6 and 2.

Results

Bulb No.	Opened to air of room at	CO_2 conc. per cent	Hours
6	10.55 a.m. 1st day	1·08±0·1%	0·9
7	12 noon	0·95	2·0
1	1.10 p.m.	0·33	3·2
2	3.0 p.m.	0·20	5·0
4	7.30 p.m.	0·03	9·5
5	11.45 p.m.	0·10	13·8
3	9.30 a.m. 2nd day	0·08	23·5
9	6.30 p.m.	0·00	32·5
8	2.30 p.m. 3rd day	0·05	52·5

Conclusion

It will be observed that the gas in the room had come almost to equilibrium with the outside air (0·03 per cent CO_2) in a few hours. The leakage half-time was $1\frac{1}{2}$ hours.

Experiment II

The Peace Room

Preparation

The room was prepared in exactly the same manner as described previously except that, since there were two observers inside, they were able to stick brown

paper all round the inside of the door frame. In addition a blanket was nailed round the outside of the door frame.

Method

Two observers remained in the room during the course of the experiment. The door was sealed immediately after the block of solid carbon dioxide was carried into the room. This block was broken into a number of pieces and weighed immediately; the total weight was 14½ pounds. The lumps were then broken into smaller pieces and fanned by hand. After about three-quarters of an hour of continual fanning and stamping, all the carbon dioxide had evaporated and the atmospheric concentration was 5·7 per cent. Breathing in such an atmosphere was difficult. Analyses were performed at intervals of about ten minutes; some samples were collected from floor level, others were taken from table level.

General Observations

(i) The wind outside was moderate. (ii) The air in the room was stirred by one of the observers walking round most of the time. (iii) Initially the pressure in the room was approximately ½ mm. (as measured on a water-gauge) less than that outside but after about an hour it rose to approximately 1 mm. above that outside.

Results

These are given in the table below and also plotted on the curve (Fig. 1) which is typical for all the measurements of this kind.

Actual readings taken in measuring the concentration:

Time p.m.	Volume of air taken	Volume of CO_2 found	Per cent concentration	Time from start (hrs.)
7.35	9·17	·005	·05	0·00
7.47	9·28	·035	·4	0·2
8.01	8·53	·13	1·8	0·43
8.09	8·685	·38	4·4	0.57
8.17	8·73	·235	2·7	0·70
(this measurement was taken on the floor)				
8.25	9·10	·52	5·7	0·83
8.42	8·83	·45	5·1	1·10
8.47	9·47	·48	5.1	1·20
(the sample for this measurement was taken from floor)				
9.05	9·07	·42	4·6	1·50
9.20	9·16	·41	4·5	1·75
9.34	8·93	·37	4·1	1·98
9.46	8·54	·36	4·2	2·19
9.54	9·47	·35	3·7	2·31
(the sample for this measurement was taken from floor)				
10.07	9·00	·34	3·8	2·53
10.28	9·195	·295	3·2	2·88
10.43	9·00	·27	3·0	3·13
10.53	9·13	·27	3·0	3·30
11.00	9·04	·25	2·8	3·41
11.05	9·08	·24	2·6	3·50

From these measurements it follows that the leakage half-time was 2·5 hours.

Experiment III

The Peace Room, 15 King's Parade, Cambridge
January 5th, 1937

Preparation

At the beginning of the experiment, the "gas proofing" of the room, which had been completed previously, was not touched, and it was not until all the dry ice had evaporated that the "gas-proofing" was removed; the object of this procedure was to ensure a high initial concentration of CO_2.

In the table below, it will be seen that 29 minutes after the CO_2 was released, the room was "stripped," i.e. the "gas-proofing" was removed, so that the experiment proper, which was to discover the rapidity of escape from a non-gas-proofed room, began at 9.29 p.m.

Method

The method employed was exactly that of the preceding experiment. The amount of carbon dioxide broken up was 9 pounds 10 ounces and the theoretical maximum concentration from such an amount is 4·1 per cent.

Results

Actual readings taken in measuring the concentration:

Time p.m.	Volume of air taken	Volume of CO_2 found	Per cent concentration	Time from start (hrs.)	Remarks
9.0					CO_2 broken up
9.06	8·48	·08	·95	·10	
9.13	8·66	·19	2·2	·22	
9.25	8·795	·305	3·5	·42	
9.29				·46	All CO_2 gone and room stripped
9.31	8·67	·29	3·3	·52	
9.35	8·615	·23	2·7	·58	
9.39	8·47	·19	2·2	·65	
9.44	8·57	·15	1·75	·73	
9.49	8·47	·12	1·4	·82	
9.53	8·515	·095	0·9	·88	
10.00	8·725	·075	0·85	1·00	

Leakage half-time was 14 minutes.

Experiment IV

The dining-room, semi-detached house, Cambridge
December 30th, 1936

The Room

This room is on the ground floor and has two doors, one opening into the hall and one into the garden. There are windows on both sides of the garden door. Volume of room was 35 cubic metres.

The blocking of the fireplace with plywood and the sealing of the window with newspaper mush is shown in photographs 3 and 4.

It was a clear moonlight night, with a moderate wind.

Method

Half the charge of carbon dioxide was liberated in the unsealed room, though the doors and windows were shut, in order to find the leakage half-time for the room when unprotected. When the rate of loss had been determined, the room was carefully sealed up in the usual way, two observers staying in the room. The rest of the dry ice was then evaporated, and the rate of loss again measured. When this had been determined, the window was opened, and the new rate was measured.

Results

In the unprotected room the leakage half-time was about 10 minutes; in the protected room it was about $2\frac{1}{2}$ hours. Opening a window of area 2 square feet, made the leakage half-time fall to 25 minutes.

Table showing actual readings taken in measuring the concentration

Time p.m.	Volume of air taken	Volume of CO_2 found	Per cent concentration	Time from start (hrs.)	Remarks
7.05	8·43	·02	0·2		
7.15					Temp. in room 58° F. CO_2 broken up
7.23	8·50	·19	2·2	·13	
7.33	8·46	·24	2·8	·30	Temp. 58° F.
7.40	8·56	·16	1·9	·42	All CO_2 gone from floor
7.46	8·545	·105	1·2	·52	
7.55	8·43	·07	0·8	·67	

In this experiment 8 lbs. 6 oz. (3·81 kgs.) were liberated in the room, giving the maximum concentration possible as 6·1 per cent.

In the second experiment 6 lbs. 11 oz. (3·04 kgs.) were liberated, giving a maximum possible concentration of 4·9 per cent.

10.00					Start to break up CO_2
10.03					Temp. of room 64° F.
10.10	8·60	·25	2·9	·17	
10.19	8·69	·40	4·6	·32	
10.20					All CO_2 sublimed
10.22					Temp. 61° F.
10.26	8·64	·40	4·6	·43	
10.37	8·27	·37	4·5	·60	
10.46					Temp. 63·5° F.
11.00	9·01	·36	4·0	1·00	
11.05	8·73	·34	3·9	1·10	

Tilted spirit gauge showed random movements of about ± 1 mm. along inclined tubes.

11.15	8·99	·33	3·7	1·25	
11.22	8·77	·32	3·6	1·37	
11.31	8·72	·31	3·4	1·52	
11.38					Window opened
11.41	8·58	·28	3·3	1·68	
11.45	8·42	·23	2·7	1·75	
11.49	8·59	·21	2·45	1·82	
11.53	8·66	·18	2·1	1·88	

Experiment V

A sitting-room in a Council house, Cambridge
Friday, January 8th, 1937

The Room

The room had a bay window, distempered walls in good condition and a wooden floor with well-fitting boards. The cubic content of the room is about 32 cubic metres.

It was a fine, calm, cold night.

Method

Exactly the same experiments were performed as in the previous Experiment (IV), except that a window was not opened at the end of the experiment.

Results

For the unprotected room the leakage half-time was about 30 minutes and with the gas-proofing 3·4 hours. The longer time in this experiment is probably to be connected with the stillness of the night. It made it necessary to take into account the generation of carbon dioxide by the two observers. The normal rate for an adult of 0·29 litres per minute was assumed. The numerical results are given in the accompanying table:

Actual readings taken

Time p.m.	Volume of air taken	Volume of CO_2 found	Per cent concentration	Time from start (hrs.)
6·10	6 lbs. CO^2 broken up on floor—volume of room 32 cubic metres (1 cubic metre of solid furniture)			
6.15	8·61	·205	2·4	·08
6.21	8·66	·375	4·3	·18
6.25	All CO_2 had evaporated			
6.28	8·51	·31	3·6	·30
6.34	8·73	·26	3·0	·40
6.38	8·74	·225	2·55	·47
6.41	8·61	·21	2·45	·52
6.44	8·65	·195	2·25	·57
6.58	8·505	·135	1·6	·80
7.01	8·58	·09	1·05	·85
8.47	4 lbs. 14 oz. CO_2 broken up—theoretical maximum conc. = 3·9 per cent			
8.56	8·70	·225	2·6	·10
9.02	Practically all CO_2 gone			
9.03	8·66	·36	4·15	·22
9.15	8·71	·34	3·9	·42
9.21	8·625	·330	3·8	·52
9.31	8·61	·315	3·65	·68
9.46	8·66	·30	3·45	·93
10.02	8·57	·30	3·5	1·20
10.09	8·535	·285	3·35	1·32
10.14	Pressure gauge showed about ½ mm. excess pressure in room, but this is not significant			
10.19	8·62	·285	3·30	1·48
10.31	8·565	·275	3·2	1·68
10.43	8·61	·27	3·15	1·88
10.58	8·69	·255	2·95	2·13

Experiment VI

The bathroom in a modern villa, Cambridge
January 12th and 13th, 1937

The Room

The walls were painted and partially tiled. The floor was of concrete covered with cork tiles. The windows were Crittall's steel windows. The door fitted very closely. Volume of room = 9·4 cubic metres.

The room was very carefully sealed. Newspaper mush was not relied upon, plasticine being used to fill all cracks round the window, and wherever pipes came into the room. The switch was covered with sticky brown paper and the door sealed with the same material.

Method

In this experiment the "dry ice" was broken up, and the room then sealed up, without any observers inside. An electric fan was arranged so that it could be switched on from the outside, and the air was stirred in this way for two minutes before any sample was removed through a tube in the keyhole for analysis. The leakage half-time for the room was $9\frac{1}{4}$ hours.

The actual readings obtained are given in the table below:

Time	Volume of air taken	Volume of CO_2 found	Per cent concentration	Time from start (hrs.)
12/1/37				
8.30 p.m. "dry ice" broken up, sealed up room				
9.05	9·58	1·02	10·6	.58
10.07	9·62	1·28	13·3	1.62
12.00	9·42	1·22	12·95	3.50
13/1/37				
7.40 a.m.	9·56	·715	7·5	11.17
9.05	9·235	·655	7·1	12.58
1.00	9·29	·47	5·05	16.50
4.10	9·36	·38	4·05	19.67
8.10	9·65	·275	2·85	23.67

Experiment VII: Test on an Air-Lock

The Peace Room, December 22nd, 1936

Weather conditions: clear and still

Preparation

The room was prepared in the manner described in the first experiment but, in addition, an air-lock was constructed by following the description in Air Raid Precautions Handbook No. 1 (p. 30). The door of the room communicates with a short passage. One side of this passage was boarded up with plywood and the air-lock was constructed with the following dimensions:

Length, 2·18 metres (at the bottom); 1·00 metre (at the top)

Breadth, 1·07 metres

Height, 2·10 metres

Note: this appendix is totally deluded. See J. B. S. Haldane's 1938 book "A.R.P." pages 21-23. Hamburg disaster proved 11 tons of phosgene in city killed VERY FEW!

THE CONCENTRATION OF GAS LIKELY TO BE ATTAINED IN AIR ATTACKS

Information on this subject may be obtained from the Hamburg explosion in 1928 and from the work of a German scientist, Dr. Hermann Engelhard (*Gasschutz und Luftschutz*, *4*, 174, 1934). In the Hamburg accident eleven tons of liquid phosgene were liberated. The casualties caused at various distances from the source of the gas are given in the following table:

WINDOWS WERE OPEN! TABLE OMITS % KILLED!

Distance from source of gas in metres[1]	Number of persons Dead	Injured
150	2	
300	3	
2,000	6	20 seriously (several died) 30 less seriously
2,700		130
14,000	limit of noticeable concentration	

SHOULD GIVE PERCENTAGES!

THIS ACTUALLY PROVES FAILURE OF PHOSGENE!

Engelhard's work is partly theoretical and partly experimental. Experiments were performed in which cylinders containing gas were arranged in a row one metre apart in an open field. There was a gentle wind

[1] 1,000 metres = ⅝ mile.

(2 metres/sec.) travelling at right angles to the line of cylinders. All the cylinders were opened at the same time, the gas taking about ten minutes to escape. One thousand cylinders each containing 20 kgs. of phosgene were used. On the basis of experimental tests the height of the gas cloud is assumed to increase more slowly after it has travelled 50 metres from the cylinders. The table gives the relation of concentration with distance from the cylinders.

Distance from gas source, in metres	Height of gas cloud, in metres	Concentration volume per cent	mg/m³
1	0·27	1·4	63,000
10	2·70	0·14	6,300
20	5·04	0·075	3,300
100	14·50	0·025	1,120
300	16·00	0·021	940
1,000	23·5	0·011	510
3,000	43·5	0·004	170
10,000	113·5		28
15,000	163·5		14

The length of time that these concentrations persist varies with the distance from the gas cylinders, the persistence increasing with the distance. Summarising the results he obtained, Dr. Engelhard states that the average concentration of poison gas which one may reasonably expect to establish over an area (unspecified) as a result of an air raid is 0·4 volume per cent.

The concentration of gas would persist for a long time in the absence of wind, decreasing more rapidly the stronger the wind, but less rapidly the larger the area over which the bombs had been dropped.

Note:

THERE IS HARDLY EVER A COMPLETE ABSENCE OF WIND. GAS IS ONLY EFFICIENT AGAINST UNPROTECTED OUTDOOR PERSONNEL OVER WIDE AREAS WHERE THERE IS AN INVERSION TO TRAP AIR NEAR THE GROUND AND TO STOP VERTICAL MIXING. RAIN DECONTAMINATES GAS

THESE FACTS WERE WELL ESTABLISHED IN WWI!

CALCULATION OF THE SURVIVAL TIME IN A "GAS-PROOFED" ROOM

(1) WHEN THE CONCENTRATION OF GAS OUTSIDE REMAINS CONSTANT the leakage into the room from the outside may be assumed to occur according to an exponential law. Thus if c_o is the concentration of gas outside the room and c_t the concentration inside the room after a time t from the moment when the gas arrived outside, then

$$c_t = c_o(1 - e^{-kt})$$

where k is equal to ·69/(leakage half-time).

The concentration of gas in the room rises continuously and we shall suppose its effect to be fatal when the victim has been subjected to a given "dose" (measured by the product of the concentration and the time during which this concentration has persisted). The "dose" is measured by

$$\int_o^{t_1} c_t dt$$

where t_1 is the time during which the gas has been leaking into the room. Using the above expression for c_t we obtain

$$\int_o^{t_1} c_t dt = c_o\left(\int_o^{t_1} dt - \int_o^{t_1} e^{-kt} dt\right)$$

$$= c_o\left(t_1 + \frac{1}{k} e^{-kt_1} - \frac{1}{k}\right)$$

Let the time taken to kill a person outside the "gas-proof" room be t_2

$$\text{Then} \int_0^{t_1} c_t dt = c_o t_2$$

$$\text{or } t_2 = t_1 + \frac{1}{k}(e^{-kt_1} - 1)$$

Values of t_2 have been worked out from this formula for various values of t_1 and of k, i.e. for various strengths of poison gas outside the room and for different degrees of gas-proofing. The value of k was found experimentally by measuring the time t^* taken for the concentration of carbon dioxide, established in the room by evaporating dry ice, to fall to half its initial value. The relation used was derived as follows:

$$c_t = c_o e^{-kt}$$

$$c_{t^*} = \frac{c_o}{2} = c_o . e^{-kt^*}$$

$$e^{kt^*} = 2 \text{ and } k = \log_{10} 2 / \log_{10} e \cdot t^* = \cdot 69/t^*$$

The rooms studied had half-value periods ranging from 10 minutes when unprotected to about 10 hours when protected. The values of t^* chosen, namely 10 minutes, 1 hour, 3 hours, 10 hours, are intended to give a survey of the results with degrees of protection likely to be found in practice. It will be seen that the survival time increases with the degree of protection, but at a slower rate.

Leakage half-time for room	Survival time outside	Survival time inside room
10 minutes	4 minutes	12 minutes
	46 minutes	1 hour
	1 h. 16 min.	1 h. 30 min.
1 hour	5 minutes	31 minutes
	17 minutes	1 hour
	55 minutes	2 hours
3 hours	6 minutes	1 hour
	24 minutes	2 hours
	50 minutes	3 hours
10 hours	8½ minutes	2 hours
	30 minutes	4 hours
	1 h. 5 min.	6 hours

(2) WHEN THE CONCENTRATION OF GAS OUTSIDE IS FALLING EXPONENTIALLY.

Let the concentration of gas outside be c_o at the time of the attack and c_t after t hours.

Then we may as an approximate statement write

$$c_t = c_o e^{-k_1 t}$$

where k_1 is of the order 4 hours^{-1}, corresponding to a fall of concentration to half-value in 10 minutes.

The rate of leakage into the room, if f is the concentration in the room, is

$$\frac{df}{dt} = k_2(c_t - f)$$

where k_2 is a constant equal to ·69/(the leakage half-time for the room).

Then $$\frac{df}{dt}=k_2(c_o e^{-k_1 t}-f)$$

$$\frac{df}{dt}+k_2 f=k_2 c_o e^{-k_1 t}$$

The solution of this equation is

$$f=\frac{k_2}{k_2-k_1}\, c_o\, (e^{-k_1 t}-e^{-k_2 t})$$

The " dose " inside the " gas-proof " room is

$\int_o^{t_1} f\, dt$ where t_1 is the time at which a lethal amount has been absorbed.

Now $$\int_o^{t_1} f\, dt=\frac{c_o}{k_1\,(k_2-k_1)}\,[k_1 e^{-k_2 t_1}-k_2 e^{-k_1 t_1}+(k_2-k_1)]$$

It is most useful to compare the time for a lethal dose inside the room, t_1, with that outside the room, t_2.

This is $$\int_o^{t_2} c_o e^{-k_1 t}\, dt=\frac{c_o}{k_1}\,(\text{I}-e^{-k_1 t_2})$$

The lethal dose is the same inside the room and outside, hence

$$\frac{c_o}{k_1}\,(\text{I}-e^{-k_1 t_2})=\frac{c_o}{k_1(k_2-k_1)}\,[k_1 e^{-k_2 t_1}-k_2 e^{-k_1 t_1}+(k_2-k_1)]$$

whence $$e^{-k_1 t_2}=\frac{[k_1 e^{-k_2 t_1}-k_2 e^{-k_1 t_1}]}{k_1-k_2}$$

The following table has been calculated using this formula.

Summary of information about the time it is possible to stay in a "gas-proof" room when the concentration of gas outside is falling to half-value in 10 minutes.

Leakage half-time of room	Lethal dose in air outside	Lethal time in room
10 minutes	2·5 minutes	10 minutes
	14 minutes	30 minutes
	36 minutes	1 hour
1 hour	7 minutes	1 hour
	18 minutes	2 hours
	28 minutes	3 hours
3 hours	**6 minutes**	**2 hours**
	12½ minutes	4 hours
	19 minutes	6 hours
10 hours	3½ minutes	4 hours
	8 minutes	8 hours
	12 minutes	12 hours

EXPERIMENTS WITH A GAS-MASK

Experiment XV

With the civilian-type gas-mask
January 6th, 1937

An apparatus was set up, whereby a measured quantity of air was blown through the filter of the 17/6 gas mask for $\frac{1}{2}$ minute, then a small quantity of chlorine, then more air, and so on. The gas issuing from the filter was passed into a solution of potassium iodide, containing some starch, in order to detect any chlorine that might pass through. In this way about $1\frac{1}{2}$ litres of chlorine at normal pressure were passed through, and 150 litres of air. The filter became appreciably warm, but all the chorine weighing approximately 4 gm. was retained.

January 12th, 1937

The same filter was weighed. A cubic foot of air was passed through it, over a period of 7 minutes, without changing the weight significantly. A mixture of chlorine and air was then blown through the filter, and this

became very hot and started to steam vigorously. Air alone was then blown through to cool the filter down. Then the chlorine mixture was blown through again; chlorine was detected coming through the filter one to two minutes later.

The total quantity of chlorine absorbed was not less than 8 gm., which means that it would withstand an atmosphere contaminated with ½ per cent chlorine for about 55 minutes at the normal rate of breathing. The pressure across the filter was measured by means of a spirit-gauge when an amount of air corresponding to normal breathing was passing through it.

Results

Weight of filter = 227·6 gm.

Weight of filter after passing 1 cubic feet of air = 227·7 gm.

Weight of filter after chlorine began to escape = 231·3 gm.

Pressure difference across filter at beginning of test = 1·1 cm.

Pressure difference when filter was hot = 4·3 cm.

Pressure difference at end of experiment = 1·0 cm.

Estimated weight of water lost by steaming = 1 gm.

Total weight of chlorine absorbed = 7–9 gm.

Experiment XVI

Test on passage of smoke through a civilian-type gas-mask

Method

A gas meter, a 2-litre flask and the canister of the civilian-type gas-mask were joined together with rubber tubing, and air blown through them from a vacuum cleaner. The rate of flow was about 1 cubic foot in five minutes, i.e. approximately the average rate of breathing. A cigarette was lighted and supported on a wire in the flask. The air currents easily kept it smoking. The smell of the smoke was first detectable when one's nose was near the canister after the experiment had been in progress for about 3 minutes. After 9 minutes the smell was quite strong, and gradually increased with time. No smoke could be seen emerging from the filter, though there was plenty to be seen on the other side. The cigarette took 25 minutes to burn away completely.

Conclusion

Very fine smoke particles probably pass through the filter, but the greater part of the smoke is stopped by it.

Note.—The smell detected in the air emerging from the canister may have been due to a true gas, hence the experiment does not prove that a smoke passed through the filter, though it is to be expected that a true gas arising under these conditions would have been absorbed by the charcoal.

Experiment XVII

Test on the passage through a civilian-type gas-mask of the irritant smoke obtained from Cayenne pepper. When Cayenne pepper is spread in a thin layer on an iron plate and very gently heated by a flame held some inches away so that the pepper begins to smoke, but does not burn, a highly irritant product is given off that causes uncontrollable coughing. This smoke was used in the experiment about to be described.

Place

A closed garage, in Cambridge
January 12th, 1937

Method

Two observers took part in the experiment; one wore a gas-mask, one did not. The smoke was generated, and the unprotected observer noted the time when he began to cough. So long as the man in the mask stood some distance away, he was unaffected, but when the filter of the mask was about a foot from the pepper, he began to cough.

Conclusion

The conclusions are similar to those drawn from Experiment XVI.

EXPERIMENTS WITH THERMITE

Thermite is a mixture of iron oxide and aluminium powder. When it is properly ignited, the mixture undergoes a very energetic reaction, great heat being emitted and iron produced in the molten state.

Experiment XVIII

The Ignition of Thermite

Place: a garden in Kent. Date: December 25th, 1936
Four observers were present

1·7 oz. of thermite enclosed in a small tin was ignited by means of a teaspoonful of flashpowder which filled a little pocket in the thermite. In this and in the following experiments, in which the same methods were used, the flashpowder was lit by means of a candle on the end of a stick. The tin rested upon a couple of logs of wood. Almost immediately after ignition the bottom of the tin melted through, and some of the powder escaped without igniting. Both logs were set alight, but it is unlikely that they would have continued to burn even indoors.

Experiment XIX

Effect of Water on Thermite

Place: a garden in Kent. Date: December 29th, 1936
Two observers present

Since the effect of water on thermite is often said to be explosive, the thermite was arranged in such a position that water could be poured over it from a height; a bucket of water being balanced on the overhanging branch of a tree.

Test 1

In order to avoid a premature dispersal of the powder, 1 lb. was placed in a flower-pot of suitable size, the hole at the bottom being covered by a piece of slate. A wooden board was covered with $1\frac{1}{2}$ in. of earth and the pot was placed on this and packed round with more earth. The "bomb" was ignited and the light radiated was measured by a photoelectric exposure meter, which during the early part of the reaction gave a scale reading of 1/10th at a distance of 11 ft. 6 in. This corresponds roughly to a source of candle-power 5,000. The reaction lasted about ten seconds and the bucket was not upset until this was just completed. The pot was smashed—though this might have been done by the falling bucket—and glowing masses of slag were scattered about by the impact. The greater part seemed to be extinguished, but part glowed for some time. No penetration of the earth or scorching of

the board occurred so far as could be observed and no explosive effect was noted.

Test 2

Conditions were as before, except that 1 lb. 6 oz. of thermite in a tin were used and a layer of earth ½ in. thick was placed between the tin and the wood (now wet from the previous test). This time the bucket was upset while the reaction was in full blast. No explosion occurred, and the main fire was dispersed, without being immediately extinguished. The thermite had penetrated the earth, burnt its way between two of the planks of the wooden door, and a glowing mass had sunk perhaps an inch into the turf beneath. The planks burned for a short time, but were soon extinguished by the water.

Experiment XX

Attempts to Shovel a "Bomb" into a Bucket of Water

Place: a garden in Kent. Date: December 30th, 1936
Four observers present

Test 1

One pound of thermite was ignited in a flower-pot standing on the bare earth. One observer, well protected by gloves, glasses (unsmoked), and scarves, tried to shovel the bomb into a bucket. The attempt failed, owing to the excessive brightness which made it impossible to see properly, but after a few trials some of the thermite was got into the water.

Test 2

Conditions were the same except that smoked glasses were used. These proved to be too lightly smoked and not much more success was obtained.

Experiment XXI

Intensity of Light from a Thermite "Bomb"

Place: a garden in Kent. Date: January 1st, 1937

Three observers present

Two pounds of thermite were placed in a tin on the wooden door used in the previous experiments and ignited. One observer with a photographic exposure meter was stationed at the distance of 17 ft. 6 in. from the bomb. The maximum reading of the meter was 1/50 which corresponds to a source of 50,000 candle-power. The molten iron from the thermite seemed to have run quickly through the cracks of the door in several places, and a glowing pool had sunk into the turf. The whole underside of the boards were burning briskly over about 2 square feet. Over part of this area they burned out gradually, after considerable charring, and about half a square foot was quite destroyed.

Experiment XXII

Penetration of a "Bomb" through Sand

Place: a garden in Cambridge. Date: January 17th, 1937

It was raining continuously. There were about 40 observers present.

The "bombs" for Experiments XXI–XXV with the exception of that used in Experiment XXIII, were made up in tins. For the experiments a wooden table provided with a second layer of board $1\frac{1}{2}$ ft. below the top was used to indicate the effects which a bomb might cause on a floor below that where it was ignited. This extra "floor" was composed of 7/8 in. new floor-board, tongued and grooved.

Two inches of somewhat damp sand were placed on the table. A previous test had shown that if an irregular 2 lb. weight was dropped from 7 ft. it usually penetrated through the sand to the wood. The "bomb" (2 lb.) for this experiment was therefore sunk into the sand at one corner to within half an inch of the wood. On ignition, the "bomb" burnt through the sand and table within 30 seconds and scattered burning materials over the lower "floor," but this did not ignite. Flames beneath the upper floor round the hole burnt themselves out gradually.

Experiment XXIII

Attempt to Shovel a "Bomb" into a Bucket of Sand

The place and time were the same as for the previous experiment. A 1-lb. "bomb" was used and ignited close to the bucket. The "bomb" was disintegrated by strokes from the spade during the attempt to lift it up. Later most of the burning parts were got into the bucket,

together with a good deal of earth. The observer said that he thought he would have succeeded if the glasses had not been so heavily smoked.

Experiment XXIV

Effect of Dropping Thermite into a Bucket of Water

A 1-lb. "bomb," made up in an iron saucepan, was ignited on a wooden lath over a bucket of water. It upset and fell in before burning through the lath. The molten iron burnt its way through the bottom of the bucket, and part came through, the rest solidifying and partially blocking the hole made. It continued to glow for some little while.

Experiment XXV

Penetration of "Bomb" through Floors

Place and time as before. A 2-lb. "bomb" was ignited on the upper floor of the wooden structure described previously. It burnt through the upper part and much of it came through to the lower (which was a piece of blackboard) but it did not ignite this effectively.

6D

AIR RAID PROTECTION: THE FACTS

By 10 CAMBRIDGE SCIENTISTS

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PREVIOUS NUMBERS OF FACT

Turn to page 3 of cover (p. 99).

AIR RAID PROTECTION: THE FACTS

By a Committee of the Cambridge Scientists' Anti-War Group:

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* We wish to acknowledge here with gratitude the assistance of Professor J. B. S. Haldane, F.R.S., and H. Joules, M.R.C.P.

also

We may summarize these various objections to the Government's plans as follows :—

(*a*) There is no necessity for any such measures, if the Government adheres to a proper foreign policy.

(*b*) The plans would result in unfair discrimination in favour of the wealthy.

(*c*) That the method of organization proposed may seriously interfere with individual liberty.

(*d*) That the plans, technically, are entirely inadequate.

* * *

(*a*) When air raid precaution measures were first proposed there seemed, neither from a study of the international situation nor from the Government's own statements, any reason to suppose they were really necessary. The situation, however, has progressively worsened since. Many people were inclined to think that it would be far more useful to direct efforts towards the abolition of aerial bombardment or even more for an arrangement for general pacification than to undertake such precautions.

This however is no place to discuss the merits of collective security versus isolation as a proper policy.

(*b*) As soon as the A.R.P. plans had been put forward widespread objections were made to the discrimination between rich and poor that they introduced. The basis of the scheme was that the householder should be responsible for the defence of his family. This meant in effect two things. First, in respect to obligatory measures of protection the burden of the cost would fall most heavily on the poorer sections of the community, thus being in effect a poll tax which is the most inequitable form of taxation. All moderately effective measures, bomb proof shelters, reinforced buildings and so forth which the householder himself had to pay for, could only be

afforded by the rich. Moreover the working class were doubly discriminated against in that they were exposed to by far the greatest danger. They are more crowded, they have less well built houses, they live near the military objectives of the attacking force, and we know from experience in Spain and China, they are also deliberately picked out for attack for political reasons, nor have they any of the facilities of escape to remote parts of the country which the wealthier sections have and are already preparing. Under any of the proposed Government schemes, they will get the least protection and pay relatively the most for it. To permit and advise people in the building of protective shelters instead of providing state shelters on an equal basis for all is to deprive the poor of shelter to the advantage of the rich. The same discrimination appeared originally in gas masks. When the scheme was first proposed the cheapest respirators available to the public cost over £2 and at this price clearly none but the rich could be protected from gas. Rumours went round that cheap masks costing about one shilling would be produced which tended if anything to intensify the campaign against this discrimination. It was quite evident that the value of a shilling gas mask could only be psychological. At that time the opponents of the schemes supported the official thesis that protection against gas was the main requirement, and the whole of the organized Peace Movement stressed the unfairness of gas-masks for the rich alone. The issue was clear-cut, and had what may best be described as ‘ election appeal ’. Consequently, after long delay the Government gave way, and in April 1936 Mr. Geoffrey Lloyd answered in the House of Commons that it was proposed to manufacture 30 million respirators for free distribution. This was not regarded as a victory by the Peace Movement,

which was still campaigning for the complete withdrawal of passive defence schemes, for the reasons summarized in (*a*). Yet in a real sense, it was a victory. If the underground shelter had as much appeal to the public imagination as had the gas-mask we might to-day be better protected than we are.

(*c*) The full magnitude of the restrictive potentialities contained in the Air-Raid Precautions Bill was not realized when the first plans were published. It was seen that the proposed air raid wardens armed with ill defined powers to 'prevent panic', could also be instructed to prevent any kind of publicly voiced opposition to war as 'dangerous to the morale of the public'. This danger was and still is insufficiently stressed. The number of wardens proposed is greater than the sum of the peace time strength of the army, navy, and air force all put together. The importance of such a standing army could be colossal. The way in which the powers of the wardens is used depends on who is in official control of them and on the wardens themselves. At present we have the position that the majority so far enlisted are working in close contact with the police. This, no doubt, makes for efficient organization but gives little chance of local democratic control.

As already mentioned, a number of scientists stated that the precautions proposed were very inadequate. Unfortunately this was misread by the unscientifically minded as meaning that the proposed methods could not save any lives at all. Many supporters of the Peace Movement made extremely inaccurate public statements as to the dangers of gas warfare; it was frequently stated that London could be so completely obliterated in a single raid that over the greater part of it every man, woman and child would be killed. In a widely circulated pamphlet

it was stated ' . . . a single bomb . . . may lay waste an area of a quarter of a square mile, and burn, poison, or dismember every living thing within it.'

Neither of these statements has any supporting evidence, and, while no doubt they were made in perfectly good faith, it was very easy for Government spokesmen to lump together all their opponents on technical grounds, and to damn them wholesale by pouring ridicule upon such easily controverted statements as the above. The average man who knows very well that whole armies were protected from gas on the Western Front is not impressed when he is told that there is no protection whatever against gas-raids. The modern high explosive bomb is sufficiently devastating without attributing magical properties to it, or inventing imaginary gases against which no protection avails. In conducting a ceremonial funeral of such red herrings, the authorities have been able to hide the fact that although the proposed schemes would undoubtedly have some protective effect in an attack with gas alone they fall very far short of what could be obtained for the expenditure of a larger amount of money and effort.

Unbridled exaggeration is in part the cause of the small effect which technical criticism has so far had upon the Home Office.

The Official Attitude Towards Technical Criticism

From the time when Air Raid Precautions in the country were embryonic, the Home Office has been extremely sensitive to comments on the efficacy of its plans for the protection of the public, and extremely reluctant to give details of crucial tests made on them by their own experts. At a time when the French Government had published minimum performance figures for

filters in French civilian masks and the results of tests on gasproofed rooms were published in the German *Gasschutz und Luftschutz*, the British civilian mask and room were simply 'perfectly effective'. Doubting this in view of the data available, a number of scientifically qualified research workers in Cambridge decided in 1935 to make what tests they could to reach an estimate of the probable protection from gas which was offered to the British public. Their experiments were published (*Protection of the Public from Aerial Attack*, Gollancz, 1937) with sufficient details to enable the validity of their conclusions to be checked. The experimenters were members of an organization known as the Cambridge Scientists' Anti-War Group, which is and was independent of any other organization except for affiliation to the International Peace Campaign and the National Peace Council. Its members held various views on politics but were united by an interest in the furtherance of work for peace; this is, however, immaterial to the validity of their experiments. A few sound criticisms on technical points, were made by individual scientists, and there was a flood of mere abuse from Government circles. The technique of discrediting unwelcome information is illustrated in a speech made by Mr. Geoffrey Lloyd (*Hansard*, Nov. 16th, 1937) 'The Anti-War movement is, of course, well known to honourable members. It was condemned as a Communist-inspired movement by the National Executive of the Labour Party, and I do not know that it is necessary to go further than that.' (This is quite unfounded; owing to a similarity of name we were confused with the Bermondsey Anti-War Movement which was condemned by the Labour Party as being under Communist influence.) Later in the same speech Mr. Lloyd indulged in a 'technical criticism': '. . . these scientists did not

measure the amount of gas which leaked into a room, but they measured the amount of gas which leaked out of a room, and then they tried to deduce by theoretical methods how much gas would have leaked into the room. I am advised by the Government's technical advisers that this procedure naturally led to important fallacies.' No M.P. inquired what Mr. Lloyd and the Government's technical advisers imagined had replaced the gas which leaked out. 'In the country of the blind the one-eyed man is king.'

Since the publication of our work Professor J. B. S. Haldane has drawn our attention to the fact that we had overlooked some work by his father on the same subject embodied in two reports of Departmental Committees of the Home Office: '*to inquire into the Manufacture and Use of Water Gas*' (1899 Cd. 9164) and '*to inquire into the Ventilation of Factories and Workshops*' (1902 Cd. 1302). In these reports Professor J. S. Haldane and 'the Government's technical advisers' measured the rate at which a gas leaked out of a room, and from this deduced the rate at which fresh air came in from outside. They used the same technique as was used by us, and reached substantially the same conclusions. It is interesting to note also that Professor J. S. Haldane used carbon dioxide in his experiments as we did in some of ours. Various people, who ought to know better, have criticized our experiments on the ground that the carbon dioxide used would be absorbed by plaster and mortar. This absorption is part of the process of setting of mortar, and all the rooms which we used are in houses many years old, in which the process is complete.

This attack was not confined to privileged onslaught in Parliament but even took the form of actionable comments on the professional competence of the scientists

themselves. Mr. R. K. Law, speaking at Hull to his constituents, (*Hull Daily Mail*, Feb. 26th, 1937) said 'Their political thesis has apparently led them very much astray in their scientific work. These experiments they have done I am told by the Home Office, are really completely farcical. They made all kinds of elementary mistakes and ludicrous blunders. The results which they got are, for all practical purposes, worthless. . . .'

What experiments had, in fact, been carried out by the authorities? None had been published concerning the free respirator. As far as we can ascertain, the only experiments on gas proofing before publication of our results were performed on disused telephone kiosks (*Lancet*, Dec. 19th, 1936) which differ in a number of particulars from an ordinary room. Nevertheless, our experiments were described as 'impracticable' and 'academic'. When pressed for details of experiments performed for the Home Office on gas-proofed rooms, Mr. Lloyd said, 'It would not be in the public interest to disclose details of the experiments on which the Government plans are based. . . .' (in reply to a question by Mr. John Parker (Feb. 22nd, 1937).

In November 1937, there were made public the details of an important experiment carried out on Salisbury Plain under the direction of a sub-committee of the Chemical Research Committee. Later (*Dec. 31st*, 1937) this was published as a Home Office White Paper Circular. These experiments are discussed in a later chapter and it is seen that even here there is no mention of some important points though it was encouraging to note that after much pressure the Home Office had performed and published at least three tests of the measures which it had long recommended, and no longer relied merely on quoting the names of 'eminent scientific advisers'.

Repeated requests were made to the Home Office by the same Cambridge Scientists for a civilian respirator on which quantitative tests could be carried out. These requests were unsuccessful, nor were details of any official tests on the filters published. Late in 1937 a firm which is a large supplier of gasmasks to the Government began to sell an apparently identical mask. A member of the Cambridge Scientists Group called to order two and one had actually been produced when he was asked to see the manager. On learning the purpose for which the masks were required, the latter stated that he would prefer to consult the Home Office before supplying them. A month later a batch was supplied but the firm stated that they could give no assurance that these were in fact similar in all respects to the Home Office pattern. Later, it is interesting to note, the firm informed a third party (not connected with this group) that the masks were in fact of the Home Office pattern.

Efforts to discredit such independent investigations continue. At an official Air-Raid Precautions meeting in Oxford on Feb. 18th, 1938, Dr. W. E. Bentall (A.R.P. Officer to the St. John's Ambulance Brigade) who was one of the speakers, told the audience that 'the Cambridge Scientists Group managed to finance a certain political party in Cambridge for nine months out of the profits of their book.' There is no truth in this statement.

2. The Probable Nature of Air Raids

It is inevitable that the probable effect of air raids on this country should be largely a matter of conjecture. We have to obtain what definite facts we can, and try to make the historical and geographical alterations necessary in applying them to this country.

The damage and casualties due to air raids on English towns during the Great War are known exactly. In addition, the technical data of the aircraft used are now known from German sources. The following table is compiled from the details given in the *Official History of the War in the Air*.

No. of raids	No. of bombs	Wt. of bombs	No. killed	Damage done
51 airship	5806	196 tons	557	£1½ million
52 aeroplane	2772	74 tons	857	£1½ million

The worst air raid in the Great War was that of June 13th, 1917, when 128 bombs were dropped by 17 'planes, 162 people were killed and 432 injured. The above figures can be accepted without reservation, but they form only the starting place of our present inquiry, for we have to take into account the rapid progress in aeroplane design during the past 20 years. Contrast 1914–18 with the present day. The two German aeroplanes most used for bombing this country were the Gotha and the Giant. The Gotha had a speed of about 80 miles per hour, and carried at the most about ½ ton of bombs, whilst the Giant possessed about the same speed (70–85 m.p.h.) and carried a ton of bombs. Exact data of modern bombers cannot, of course, be obtained, but the

following figures can be taken as a conservative estimate, and show the great increase in carrying capacity, and above all speed.

Medium bomber Speed	250–280 m.p.h.	Load ½ ton
Heavy	160–190	Load 2 tons

The most marked change had been therefore, a twofold to threefold rise in the speed of bombing aeroplanes. This is important in a number of ways. In the first place, it greatly reduces the time of warning that can be given of an approaching raid. This is particularly so in the case of an island like Great Britain, for there is little chance of detecting the aircraft over the sea, and supposing that they were sighted at the coast there would be at most an interval of 20 minutes between the warning and their arrival over London. Further we must take into account an increase in efficiency which is not shown by the above figures. Aeroplanes are more reliable, and the technique of flying at night and in bad weather has greatly improved. Thus the night mail flies regularly from Croydon to the other European capitals in all weathers. The conclusion seems to be that raids will not be dependent on weather conditions to anything like the extent that they were in the past.

It is natural to look to Spain to gain information on the nature of air raids. It is clear that since the Great War they have increased greatly in deadliness. According to the Mayor of Barcelona, (*Times*, Feb. 17th, 1938) the air raid record of Barcelona for the past 12 months was 23 bombardments, 528 bombs dropped, 916 deaths, 2,500 wounded and 863 houses destroyed. The intensified air attacks since then have greatly increased the number of victims and it has been reported that there have been 815 killed and 2200 injured in five days. (*Times*, March 21st, 1938).

publicly confirmed these suspicions in the House of Commons. On Monday, Nov. 15th, 1937, introducing the Second Reading of the A.R.P. Bill, he said this (*Hansard* col. 42):— Sir Samuel Hoare:

'We must have, in the first place, an Air Force that is enough to maintain the initiative in air fighting; secondly, anti-aircraft guns supported by search-lights and the other methods of modern detection; and thirdly, on the ground, a system of air-raid precautions that will achieve two objectives: that will, in the first place, ensure the country against panic, and, in the second place, will ensure that the services of the country, without which a civilized community cannot exist, will continue to be maintained. An Air Force that is deficient in either of these two fields is in a position of direct inferiority to an Air Force that is supported in these two fields. An Air Force may have the same number of first-line machines as that of a hostile power, but if it is not supported by an effective system of anti-aircraft guns and searchlights, and an organization on the ground, it will have a greater difficulty in preventing a panic and a rupture in the national life than that Air Force which is not in a position of this inferiority.

'Further than that, it will be impeded at every turn in carrying out its tactics and its strategy. Inevitably, if there is no effective ground organization, when an air attack takes place there will be such an outcry from the various centres of population for local defence that the Air Force will be tied down to the local defence of this or that centre of industry or population. How well I remember, when I was at the Air Ministry Lord Trenchard, the pioneer of air strategy, saying to me over and over again, "The Air Force that is tied down to local defence will not be able to maintain its initiative and

strategy. It is an Air Force that has lost the air war." '

This speech contains no reference to the saving of human life as a reason for having Air-Raid Precautions.

So now we know, on the best authority, that the purpose of A.R.P. is to increase the striking power of the R.A.F. In the light of this, much that was difficult to understand has become obvious.

A. R. P.

by

J. B. S. HALDANE, F. R. S.

LBC

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NOT FOR SALE TO THE PUBLIC

This Month's Book

A.R.P.

By Prof. J. B. S. Haldane, F.R.S.

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Haldane proves

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millions of pounds

but it will save (in the event of war)

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including your wife's, your children's, your own

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John Strachey writes:

"THE LEFT BOOK CLUB has published many kinds of books. It would be invidious to say of any one of them that it was the most important which the Club had ever issued. But I venture to say, after reading every word of it twice, that Professor Haldane's *A.R.P.* is the most practical book that the Club has ever issued.

"The word 'practical' is used in a very specific sense. This is a book which explains very clearly the nature of a danger under which we are all living, and urges that we take certain steps to guard against it. After reading and mastering its contents, I for one feel the most intense urge for action. I have felt vaguely before, as I suppose most of us have, that we and our families were in danger of some day being bombed from the air, and that something ought to be done about it. After reading this book, I know how very much greater that danger is than I had realised; but I also know precisely how that danger can be averted; moreover I know that that danger must be averted and that it will only be averted by the result of the most intense activity, agitation and pressure on my part and on the part of the other private citizens of Great Britain. I cannot doubt that the reading and study of this book will have the same effect on the 50,000 odd members of the Left Book Club; on the unknown hundreds of thousands of persons to whom members will lend or give this book, and, through them, on the entire British public. . . .

"I am inclined to think that upon the use which we, the 50,000 L.B.C. members, make of this book may well depend our future fates. Unless I am mistaken, this book is destined to be the foundation of an ever growing campaign which will not end until we have obtained 'full protection.' Left Book Club members often want something practical to do. Can one do anything else quite so practical as to secure for oneself and one's fellow citizens full protection against the horror of aerial bombardment? Professor Haldane has shown us that we can have full protection, though only by a scheme on a great scale such as it is idle to suppose that the Government will undertake unless an enormously strong public demand is generated. For my part, I can only say that full protection is what I demand for my wife, my two children, and myself, and that nothing less will do. Now that I know how it can be got, I will not rest until it is there."

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I. ORDINARY MEMBERS

What Membership means

The aim of the Left Book Club is a simple one; it is to help in the terribly urgent struggle *for* World Peace & a better social & economic order & *against* Fascism, by giving (to all who are determined to play their part in this struggle) such *knowledge* as will immensely increase their efficiency.

Ordinary Members of the Club receive each month one "Book of the Month"—a book *never before published*, the special edition of which is in the hands of members on publication day. This special edition for Club members is 2/6. The ordinary edition for the general public for each such selected book is not less than 5/–, & is usually 7/6, 12/6, or even 18/–. Members cannot, of course, select their own "Book of the Month." They must accept the one selected, & specially printed, for them.

No Subscription whatever

¶ There is no subscription of any kind. The member's sole responsibility is to undertake to pay for this one monthly book (after receipt of it) at the price of 2/6. ¶ The books are selected by Laski, Strachey, and Gollancz.

¶ Each member undertakes to pay for the one monthly selected book for 6 months—6 books in all. If he wishes to discontinue membership at the end of the 6 months, he must give notice in writing not later than four and a half months after the date on which he signs the coupon overleaf. If he does not give this notice, his membership will continue indefinitely, but may be discontinued *at any time* by giving 6 weeks' notice in writing.

But Membership is a Key . . .

While there is not the faintest obligation on any member to do more than buy the one monthly "Book of the Month" & pay his half-crown for it, membership is a key that unlocks the door to a wide range of extra books at low prices.

¶ Every month a card is inserted in *The Left News* (the Club bulletin which goes free each month to every member) giving a number of extra books which are offered to members, & to members only, at prices far lower than those ruling for the public. Month by month members can (but only if they so wish) apply for one, some, or all of these extra books. Most of these extra books are completely new; a few are reprints.

¶ As examples of these extra books, we may mention *The Private Manufacture of Armaments* by Philip Noel-Baker (ordinary price 18/–, Club price 4/6); *Soviet Communism* by Sidney & Beatrice Webb, revised edition, (ordinary price 35/–, Club price 6/–); *The Irish Republic* by Dorothy Macardle, with a Preface by President de Valera (ordinary price 25/–, Club price 7/6); *An Atlas of Current Affairs* by J. F. Horrabin (ordinary price 3/6, Club price 2/–); *Modern Marriage & Birth Control* by Dr. E. F. Griffith (ordinary price 5/–, Club price 1/6).
¶ The Club also publishes a series of very simple "Educational" books, forming basic introductions to important questions—such as *Money*, *Unemployment*,

Trade Unionism, Civil Liberties, Italian Fascism, etc. Ordinary price 1/- & 1/6 each, Club price 6*d.* each. It is, of course, entirely within the option of members whether they take any of these books.

¶ There is a Club edition of every book published by Messrs. Lawrence & Wishart (past, present, or to come) at two-thirds of the ordinary price. Any of these books can be bought by Club members at the special price at any time. Lawrence & Wishart publish many of the works of Marx & Engels, & have practically a monopoly of the works of Lenin.

¶ Members receive free each month, with their " Book of the Month," *The Left News*. This is an important political paper, with articles by Laski, Strachey, etc. It also contains full information of all activities and meetings of the Club & its 962 local groups (see below), describes the Club books, & announces each month the extra books offered to members that month—an application card for these extra books being enclosed. The price of *The Left News* to members of the general public is 3*d.*

What the Club has become

The Club was founded (in May 1936) merely to provide machinery by which books of urgent political importance could be issued at a very low price—so that *the people* might *know* & no longer *be deceived.* We hoped to get 10,000 members, each one of whom would spread the information obtained in wider circles. But we aimed too low. By the beginning of this year we had 50,000 members—& we aim at 60,000 by Christmas. Such rapidity of growth has never been known in the political history of this country.

Moreover the Club, designed as a piece of *machinery*, has become a *fellowship*. There are now close on 1,000 local Left Book Club Groups, in which progressive men & women of all parties meet together to discuss the Book of the Month & hammer out their differences: as a result, these Groups are often the real activising element in the political life of the district.

Then the Club has great Rallies & political meetings all over the country, summer schools, week-end schools, a Left Book Club Theatre Guild with 250 local branches; & other activities too numerous to mention.

It should be emphasised, however, that a member still has only *one* obligation—to accept the monthly book: he need not take the smallest part in the life of the Left Book Club as a movement, unless he so desires. But new members are advised to read the first number they receive of the *Left News* without delay, as this will give them a good idea of the Club's work as a movement, & they can then decide whether they wish to associate themselves with this side of our activities.

In the desperately urgent political situation at home & abroad we believe that a doubling of the membership of the Left Book Club (every member being a *centre* of influence) can save our country & perhaps the world.

Next four "Books of the Month"

[**N.B.** *This list is provisional and subject to alteration, whether by deletion or addition of titles or the alteration of their order.*]

	Price to public (probable)	*Price to Club*
SEPTEMBER: A.R.P. by Professor J. B. S. Haldane. (See special insert.)	7/6	2/6
★**OCTOBER: Secret Agent of Japan** by Amleto Vespa. With an introduction by H. J. Timperley, China Correspondent of the *Manchester Guardian.* These astonishing revelations (by an Italian who became a Japanese Secret Agent) of the aims & methods of Japanese imperialism will create a world-wide sensation. Vespa's sphere was chiefly Manchukuo, and his description of Japanese methods there makes the blood run cold. Edgar Snow writes: "*Vespa's astounding revelations of the secret technique of Japanese militarism should create a greater international sensation than would have been made by Bruce Lockhart's 'British Secret Agent' had that volume appeared in the midst of the World War.*"	10/6	2/6
NOVEMBER: Comrades & Citizens by Seema Rynin Allan, with an Introduction by Beatrice Webb. This is the best descriptive book about the Soviet Union that we have read. The authoress, an American, spent some years working there & she describes in a wonderfully vivid way the people she met and what they were doing. The whole book " reads like a novel " but, at the same time, its truth cannot be doubted.	10/6	2/6
★**DECEMBER: China Fights Back** by Agnes Smedley. Agnes Smedley accompanied the 8th Route Army (formerly the Red Army) at the front from August 1937 until the beginning of this year, & her record is both intensely interesting & intensely moving.	7/6	2/6

Saving on these 4 books - - 26/-

2. "B" MEMBERS

" B " membership is designed to meet the difficulties of those who feel a general interest in the Club & would like to join but (*a*) cannot afford 2/6 a month for a minimum of six months—15/- in all, (*b*) feel they cannot read a book every month, (*c*) want only the more " thrilling " type of book—books, that is to say, which, while of " Left " political importance, are of great " general reader " interest.

A. R. P.

by

J. B. S. HALDANE, F.R.S.

SEPTEMBER
1938

LONDON

VICTOR GOLLANCZ LTD

1938

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APPENDICES

PREFACE

THIS BOOK IS intended for the ordinary citizen, the sort of man and woman who is going to be killed if Britain is raided again from the air. I believe that you, readers, can enormously reduce your own risk of being killed and the risk of your children being killed if you demand the necessary protective measures. I have seen the results of air raids during the present year, and I feel that I should be guilty of innocent blood if I did not make every effort in my power to save the people of Britain from the fate which is now befalling the peoples of Spain and China.

So much has been written on the subject of air-raid protection that many people will think that there is no need for another book. I do not agree. Most of the books and pamphlets on the subject seem to me to be of the nature of propaganda rather than truth. The Government and its supporters try to persuade us that we have only to follow the official instructions to be safe. I believe that this is untrue. But a great many opponents of the Government state that such things as gas-masks and gas-proof rooms are completely useless, that London could be wiped out in a single air raid, and so on. I believe that this is equally false. Even though I am convinced that the Government measures, as a whole, are inadequate, I shall give them credit for what they have done to protect us.

I shall not please those readers who take the view that the present Government can be trusted to do all that is necessary; nor yet those who think that it can do nothing right. For I believe that the matter is too important to allow my political views to interfere in any way with a strict adherence to truth. I have seen children killed in air raids, and I think that a frightful responsibility rests on those who expose British children to such a death in order to score a point for or against Mr. Chamberlain. So those who have bought this book merely as a source of political propaganda and not with a view to saving their lives and the lives of their fellow-citizens need read no further.

As I am attacking the views of experts, both on the side of the Government and against it, I must be excused if I state my own qualifications. From 1905 to 1922 I was associated with the work of my late father, J. S. Haldane, C.H., F.R.S. This research was concerned with the ventilation of mines, factories, schools and ships, and with the effects of various gases on the men who breathed them. For this work J. S. Haldane was made President of the Institution of Mining Engineers, and received numerous other British and foreign honours. In 1915 J. S. Haldane was sent over to France to devise measures of protection for the British army against German gas attacks. I was at that time a captain in a British infantry battalion and was brought out of the trenches to St. Omer, where I assisted my father in the design of some of the first gas masks.

Apart from this, I have published at least a dozen scientific papers describing research on the physiology

of breathing. I have a certain acquaintance with explosives, having commanded a bombing school for a year in 1915–1916, and as I was wounded in 1917 by an aerial bomb, I can claim a first-hand acquaintance with these weapons. In 1924 I was appointed a member of a Cabinet Committee on aerial defence, and served on it for some years, under the first Labour Government and the Conservative Government which succeeded it. This is as a matter of fact a slight handicap, as the Official Secrets Act forbids me to mention certain topics discussed by this committee. But it permits me to speak with a certain degree of authority. In the years 1936 to 1938 I spent nearly three months in Republican Spain, and was present during a number of air raids. As a result of this experience I largely modified my former views as to the relative danger from incendiary and explosive bombs, and as to the possibilities of defence from them.

Before my last visit to Spain, which was made in order to study air raid precautions there, I was asked by an official of the Foreign Office whether I would put the information gained at the disposal of the British Government. I said that I would be very glad to do so; but although I returned in January 1938 the Government has not asked me any questions on the matter. As I believe that the lessons of the Spanish war are quite literally matters of life and death to the British public, I have no option but to write this book. I have however been appointed a member of a committee of the Labour Party on Air Raid Protection, and hope also to be able to do something of value through Parliamentary channels. But I am absolutely

convinced that nothing short of a great national movement on non-party lines will force the Government to protect the people from the real and terrible danger which awaits them.

I shall do my very best to make this book intelligible to every reader. But one real difficulty must be faced. Many of the questions which are asked concerning Air Raid Precautions are unanswerable in the form in which they are put. If I am asked "Does any gas mask give complete protection against phosgene" the only literally true answer is "No." One could not live in a room full of pure phosgene in any of them. And one would be killed if a hundred-pound phosgene bomb burst in the room, even when wearing the very best mask. But one would be safe in a phosgene concentration of one part per thousand, of which a single breath would probably kill an unprotected man. Hence in practice such a mask is a very nearly complete protection.

It is the same with shelters. There are bombing 'planes which can carry four tons, and if one of these concentrated all its effort on carrying a single four-ton bomb, and aimed exactly right, it would no doubt destroy a shelter which was safe against bombs weighing one ton. Nevertheless I shall call a shelter bomb-proof if it will stand up to a one-ton bomb.

It follows that the answer to almost every question must involve numbers. I have tried to banish the most technical parts of my argument into Appendices. But I hope that even these are readable. Nevertheless the main argument can be followed without them.

built house gives fairly complete protection against these splinters, as against machine-gun bullets. And for both these reasons it is desirable to stay indoors during an air raid.

GAS AND SMOKE

A brief technical account of the most dangerous kinds of gas is given in Appendix I. They are as follows:—

1. Non-persistent gases, such as phosgene. They can be dropped in bombs which burst, and suddenly let loose a cloud of gas, which is poisonous when breathed, but which gradually disperses. If there is a wind the dispersal is very quick; in calm, and especially in foggy weather, it is much slower. These gases can penetrate into houses, but very slowly. So even in a badly-constructed house one is enormously safer than in the open air. Even the cheapest type of gas mask, *provided it fits properly and is put on at once*, gives good protection against them (see Chapter IV).

2. Persistent gases, such as mustard gas. Mustard gas is the vapour of an oily liquid, which I shall call mustard liquid. So far as I know this has not been dropped from aeroplanes in bombs on any great scale. It was used very effectively by the Italians in Abyssinia, who sprayed it in a sort of rain from special sprayers attached to the wings of low-flying aeroplanes.

Mustard gas not only attacks the lungs and eyes, but the skin, on which it raises blisters. A respirator will protect the eyes and lungs, but not the skin.

⇒ AKIN TO NERVE GASES!!!

quite small areas, say 3,000 of them, if twenty bombers dropped 150 twenty-pound bombs each, and all the bombs burst. In this case if the air-raid wardens were efficient, almost everyone could quickly be moved into a gas-free area.

If the mustard liquid could be sprayed evenly, things would be far more serious. All the outside air of a large town would be poisonous for several days. But this would only be possible if the spraying aeroplanes could fly to and fro over the town in formation, and at a height of not more than 300 feet or so. A fine rain of mustard liquid would probably evaporate on its way to the ground, or blow away, if it were let loose several thousand feet up in the air. Spraying from low-flying aeroplanes was possible in Abyssinia because the Abyssinians had no anti-aircraft guns and no defensive aeroplanes. It would probably not be possible in Britain.

Bombs liberating poisonous smokes would let loose an amount of smoke far less than the amount of gas liberated by gas bombs. For it is necessary to heat the chemical which liberates the smoke. This needs a special device which must be solid enough to stand the shock of landing. So a large part of the weight of a smoke bomb must consist of metal, and from the killer's point of view, this metal is wasted.

THE HAMBURG DISASTER. Fantastic nonsense has been talked about the possible effects of gas bombs on a town. For example, Lord Halsbury said that a single gas bomb dropped in Piccadilly Circus would kill everyone between the Thames and Regent's Park. Fortunately, although no gas bombs have been dropped

in towns in war-time, there are recorded facts[1] which give us an idea of what their effect would be. On Sunday, May 20th, 1928, at about 4.15 p.m., a tank containing 11 tons of phosgene burst in the dock area of Hamburg. The weather was warm, and there was a mild, north-easterly breeze. The gas-cloud passed mainly over open spaces, but it also passed through the suburb of Nieder-Georgswerder. There was no warning. Most of the victims were out-of-doors, playing football, rowing, or even going to vote in an election. The windows were open, so a few people were killed indoors, at least one on the first floor.

Casualties occurred up to six miles away. In all 300 people were made ill enough to be taken to hospital, and of these ten died. About fifty of the rest were seriously ill. These casualties are remarkably small. They would have been much greater had a southerly breeze taken the cloud into the main part of Hamburg. But they would probably have been nil had the people received ten minutes' warning, so that they could have got into houses and shut the windows.

No doubt enemy aeroplanes would have dropped the gas in a more thickly populated area. But they would not have taken people by surprise, and the casualties would probably have been about the same, perhaps less if they had gas masks. Eleven tons of gas could be carried in about fifteen tons of bombs. Now fifteen tons of high explosive bombs would cause 600 casualties on the basis of the figures for England, in 1917-1918, and considerably more, probably 1,500,

[1] Hegler, *Deutsche Medizinische Wochenschrift*, 1928, p. 1551.

on the average for Barcelona in 1938. Of these casualties not one in thirty, but one in two or three, die, and many of the rest are permanently mutilated. Besides this, buildings are destroyed, and roads blocked. On this estimate the explosive bomb is very considerably (perhaps fifty times) more deadly than the gas bomb.

It is sometimes objected that the Hamburg explosion occurred in the summer, and that gas clouds liberated in summer are ineffective. It is true that in winter they stick more closely to the ground. On the other hand windows are shut. And a critic at a meeting informed me that the Hamburg cloud "must have" gone straight up into the air. In spite of which it injured people on the ground six miles away. Even if we granted that the killing effect would have been five times as great in winter, which I personally doubt, the effect would still have been much less than that of high explosives.

WHY GAS WAS NOT USED IN SPAIN

In view of the terrible stories as to the effects of gas, many people are surprised that it has not been used in Spain. First, why was it not used against the loyalist army? Secondly, why was it not used against towns? The soldiers had respirators after about February 1937, but were not well trained in their use, and often lost them. Very few civilians had any respirators at all.

Gas was not used in the field for several reasons. The main reason is that the number of men and guns per mile was far less than on the fronts in the Great War. Gas is effective if you have a great deal of it,

but the amount needed is enormous. Thus during the night of March 10-11th, 1918, the Germans fired about 150,000 mustard-gas shells into an area of some twenty square miles south-west of Cambrai. If most of the air in a large area is poisoned the effects are serious. But if a few gas shells are fired or a few cylinders let off, the gas soon scatters and ceases to be poisonous, and a man can often run to a gas-free place, even without a mask, before he is poisoned.

Gas was not used against the towns for this reason, and for another, which is very important. Gas only leaks quite slowly into houses, particularly if there are no fires to make a draught, and draw in outside air; and there is very little fuel in loyal Spain. It is difficult to give exact figures. But I think it is certain that at least ten times as much gas is needed to poison people in houses as to poison them out-of-doors. Further, in the large Spanish towns most of the houses are tall, and very little gas indeed would reach the third or fourth floor of a house.

Nevertheless a good many people would have been killed by a gas raid on a large town. *Such raids were not carried out for a perfectly simple reason. A great many more people can be killed by a given weight of high explosive bombs than by the same weight of gas bombs.* Franco's friends in England say that he does not use gas for humanitarian reasons. Anyone who has seen even a few children killed by high explosive bombs will dismiss this statement as nonsense.

If then gas was not used against the Spanish towns where the civilians had no respirators, I believe that it will not be used on any great scale against British

towns, particularly after the promised supply of respirators becomes available for British civilians.

This is not to say that it will not be used at all. It is not unlikely that a few gas attacks may be made for several reasons. Mustard liquid may be dropped on certain key areas so as to disorganize transport or production for several days on end. It may be hoped that a panic will be produced. And it may be desired to confuse the British defensive effort by making a certain amount of anti-gas measures necessary. It is much easier to defend yourself against explosive bombs alone than against explosives and gas.

INCENDIARY BOMBS

These bombs usually contain thermite, which is a mixture of 23 per cent of aluminium powder with 77 per cent of iron oxide (Fe^3O^4). Other mixtures are said to have been used, for example one containing calcium; and the bomb may be made of magnesium, so that it burns. When such a mixture is heated, the aluminium unites with the oxygen of the iron oxide, and a mixture of alumina slag and white-hot molten iron is produced. This throws out some sparks, but the main effect is downwards. The molten iron penetrates wood, or even thin metal, like so much butter, and sets light to anything inflammable which it touches. Thermite is used in industry for welding.

There are other types of incendiary bomb, for example the phosphorus bomb, which throws burning fragments for some distance, and generates a great deal of smoke. But though it is more alarming, and

more likely to burn people who try to put it out, it has no penetrating power, and the heat is not so great at the centre.

These bombs may weigh from about 2 to 50 lbs. So a bombing aeroplane can carry a thousand or more of the smallest type, and scatter them over a town. About one tenth of central London is covered by houses, and if one bomb in three which hits a house sets it alight, a single aeroplane might start thirty or fifty different fires, and a squadron could cause over a thousand at once, which would be more than the fire brigades could deal with.

Such is the theory, and before 1936 it appeared reasonable. I have stated in print that the incendiary bomb was as great a danger to London as the explosive bomb. The German Air Force authorities also seem to have held this theory. But it was wrong. Like a great many other theories, it did not work in practice.

In the early aerial bombardments of Madrid in 1936 a great many incendiary bombs were used. But they were vastly less effective than was expected. The total number of buildings destroyed by them was twenty-three,[1] whereas many hundreds were destroyed by explosive bombs. After the middle of December 1936 no more incendiary bombs were used on Madrid, and they were not used on any great scale against Barcelona, Valencia, or Sagunto, though a few heavy ones weighing 30-50 lbs. were used on Barcelona in

[1] I am not absolutely certain of this figure, which was that given at an exhibition relating to Madrid, and held in Barcelona in December 1937. As a foreigner in a city under bombardment, and infested with spies, I did not consider it healthy to take too many notes. I am, however, completely certain that the number officially given was under thirty.

the spring of 1938. They were used fairly effectively on Guernica. But Guernica is a special case of a small town with no real defence raided continuously for many hours (see p. 50). So long as a British Air Force exists this can hardly happen in Britain.

I do not know the reasons for their failure. A good many did not light. Thermite is not very easy to ignite, and it may be that the ignition mechanism was smashed by the fall. It is also possible that on the whole less wood is used in Spanish than in British houses. But the average Spanish house certainly has wooden floors (except for the ground floor) and rafters. It may be added that they would be very effective against wooden houses, which are common in many parts of the U.S.A., China, Japan, and the U.S.S.R.

Whatever may be the reason, incendiary bombs are far less dangerous to British towns than high explosive bombs. These latter constitute the main danger against which we ought to guard.

HIGH EXPLOSIVE BOMBS

These bombs weigh anything from about ten pounds up to one ton, though bombs weighing $1\frac{1}{2}$ and 2 tons are said to be in existence. In the ordinary bomb anything from one-quarter to one-half the weight consists of explosive. For it need only be a thin metal case full of explosive. It does not have to stand any shock till it actually hits the ground. On the other hand a shell has to be very solidly made to stand the shock of firing from a gun. If it bursts prematurely it may kill the gun's crew. Whereas a bomb which breaks up

on hitting the ground at worst fails to explode. So a 15-lb. shell may contain less than 2 lbs. of explosive. Thus, an aerial bomb is commonly about five times as destructive as a shell of the same weight.

There are, however, two kinds of bomb which contain a larger proportion of metal. One is the armour-piercing bomb, which is made of solid steel, and is intended for use against ships and forts. The other is the small fragmentation bomb, intended to give the maximum amount of splinters when bursting. This is used against soldiers in the open, crowds, and traffic.

A bomb may burst on impact, or have a delayed action. Clearly a fragmentation bomb must burst on impact. It is almost harmless if it buries itself in the ground before bursting. On the other hand an armour-piercing bomb must penetrate as far as possible before it bursts.

WHAT IS AN EXPLOSION?

In order to understand the effects of an explosion, it is necessary to explain what is meant by the word. An explosive is a solid which can be changed very suddenly into hot gas. The word gas is used in science for anything which has the same kind of physical properties as air, for example lighting gas in the gas pipes, water-vapour in the cylinder of a steam engine, or the burning vapours in a candle flame.

Now when a solid or liquid is changed into gas it expands a great deal. For example a cubic inch of water expands into a cubic foot of steam. And when the gases are very hot they occupy still more space.

The blast of high explosive bombs would disperse gas, but this would not apply if the gas were dropped even five minutes after the explosive bombs.

PANIC

Panic can be a direct cause of death. If too many people crowd into a shelter, especially one with narrow stairs leading to it, they may easily be crushed to death. In January 1918 fourteen people were killed in this way at Bishopsgate Station in London, and sixty-six were killed in a panic in one of the Paris Underground stations as the result of a false gas alarm.

Possibly the indirect effects of panic are even more serious. If a hostile air force can once get the population of a town on the run, they can shoot them with machine-guns and attack them with light bombs which burst on hitting the ground and break up into innumerable splinters. A large fraction of the refugees from Malaga were massacred in this way in 1937.

And a panic is very hard to resist. Brave men who would certainly have held their ground if they had been alone, find themselves running if enough others start to run. For this reason anti-panic measures are of the greatest importance.

BACTERIA AND OTHER MICROBES

It is possible that these will be used in some kind of spray or dust. The difficulty is a technical one. It is easy to disperse many solids as smoke. But this needs heat, and cooked bacteria are harmless. Many

bacteria are killed even by drying. And once bacteria are on the ground they generally stay there. Possibly pneumonic plague or some other air-borne disease might be started by a dust-bomb. Cholera bacilli might be dropped in a reservoir. But they would probably be stopped by filters, and even without this would be likely to die before they reached the houses.

A million fleas weigh very little, and could easily be dropped. In theory they could be infected with plague. In practice this would need a staff of hundreds of trained bacteriologists, and huge laboratories. So with other possible means of infection. Some may very well be tried, if only to create a panic, but I would sooner face bacteria than bombs.

WILL THERE BE NEW TYPES OF GAS OR EXPLOSIVE?

A great many authors have given terrible pictures of future wars, where new types of explosive and gas are used. H. G. Wells has been a rather serious offender in this respect, painting terrible pictures of great cities wiped out in a single air raid, and wide areas poisoned for years on end.

We now know enough about the theory of chemical reactions to say that there is a definite limit to the amount of heat or other sorts of energy which a given weight of matter can yield. And we know that our existing high explosives are quite close to the upper limit. Actually there is no "better" high explosive for military purposes than trinitrotoluene (T.N.T.) which was discovered in 1879.

Of course if it is ever possible to gain complete control of changes in the nuclei of atoms such as cause radioactivity, much more formidable explosives will be possible. But at present we can neither speed these reactions up nor slow them down to the slightest extent, even in the laboratory, let alone in a bomb.

As for new gases, the possibilities are slightly greater, but not very serious, for the following reasons. There are plenty of substances which, per unit weight, are more poisonous than mustard gas; for example diphtheria toxin and the active substances in some snake venoms. But these are all substances with large molecules, much too large to form a gas or vapour. Only small molecules can do this. Now for over a century chemists have been making new organic compounds. And they have already made most of the possible types of small molecules. Mustard gas was discovered in 1886, and nothing worse had been produced by 1918. Lewisite is about as bad, but the Germans tried it and turned it down in favour of mustard gas. So, though it is possible, it is not very likely, that more effective poisonous gases will be invented.

Even if they are, it is fairly certain that they will be stopped pretty completely by the charcoal filter of a respirator. This stops all poisonous gases and vapours except those of low boiling point such as carbon monoxide. As these latter have very small molecules, it is reasonably sure that we can expect no surprises among them. So even if a new gas is produced, it is very unlikely that it will get through our respirators.

The danger from a new type of smoke is more

serious. The civilian respirator is much less efficient at stopping smokes than the service types. And even if it is good enough to deal with the smokes at present known (which many people doubt), it might fail against a more penetrating kind of smoke.

Nevertheless such a danger is rather remote. And efforts against it, though they should be made, are a vastly less urgent question than an attempt to combat the very real menace of the high explosive bomb.

KILLING POWER

Between January 1917 and November 1918 German aeroplanes dropped 71 tons of bombs on England. These killed 837 people and wounded 1,991. On March 16–19th, 1938, 41 tons of bombs were dropped on Barcelona by German and Italian aeroplanes. They killed about 1,300 people. Thus the number killed per ton went up from 12 to 32. However, Barcelona was practically undefended, owing to the "non-intervention" agreement. And it was crowded with refugees. Had it been defended the aim would have been worse and the casualties somewhat less. On the other hand there were bomb-proof shelters for about one sixth of the population. We may take 20 deaths per ton as rather a low figure for modern aeroplanes. Thus 500 aeroplanes carrying two tons each could kill about 20,000 people.

Tortosa was reduced to rubble like many French towns in 1914–1918. Sections of the army ran away. In an attempt to win the war by a knock-out blow Barcelona was again bombed. From 10 p.m. of March 16th to 3 p.m. of March 18th there were 13 raids. In none of them did more than 9 bombing aeroplanes take part. It is estimated that 41 tons of bombs were dropped, the majority weighing one or two hundredweight, whilst some weighed half a ton. 1,300 people are said to have been killed, and 2,000 wounded. 1938

As this series of raids probably gives the best idea of what we may expect in a future war, the details are of interest. Those given[1] by Mr. Duncan Sandys, M.P., are of particular interest, since he is a conservative, and is unlikely to exaggerate facts in such a way as to discredit the value of the precautions taken or proposed by the present British Government. He states that the incendiary bombs weigh about 35 lbs. (others say 50 lbs.) and that about 60 per cent fail to ignite. Of the remainder probably only 15 per cent fall on houses, so that about 700 lbs. of bombs are needed to start a single fire. Hence "the fires which they ignited have not led to any widespread outbreaks, and the regular fire brigades have found themselves well able to cope with them."

The main effect was from lateral blast and shock. "In one place I measured the frontage of the buildings that had been totally demolished, and found that it was well over 200 feet in length. That is equal to about a dozen or so average-sized London houses. As might be expected, the buildings actually struck

[1] *A.R.P. News*, Vol. I, No. 1.

newspapers or broadcast when war threatens. But they will be carried out much more completely if we know about them in advance. Can it be that the authorities have not yet made their minds up?

I presume that all arrangements have been made for darkening trains, since this can be done directly through a few railway companies. But here again the public may have to co-operate. Even if the lights are dimmed we may have to keep the blinds down at night. And the more we can learn in advance about out duties the less confusion there will be should war come.

GAS-PROOF ROOMS

We are given rather full instructions as to the preparation of what is called a refuge-room for each house. It is supposed to afford fairly complete protection against gas, and partial protection against bomb splinters. We shall deal here with the question of gas-proofing. The adequacy of protection against incendiary and explosive bombs will be considered later.

The basement is regarded as the safest place, but any floor except the top may be used. An obvious remark, which Sir Samuel Hoare does not make, is that a room with only one external wall is safer both from gas and splinters than a room with two. Elaborate instructions for gas-proofing are given. Ventilators,

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suitable screens of a design not yet disclosed it had better not be used at night. Just how such screens are to work is not clear. Even if the lamps do not shine directly upwards, how is an illuminated number-plate to be visible from the road, but not from the air?

keyholes and cracks in the wall or between the floor-boards are to be filled with putty or sodden newspaper. The chimney is to be blocked with paper, rags, or sacks, and the front of the fireplace sealed with ply-wood and adhesive tape. Finally a blanket is to be nailed to the doorway, fastened with strips of wood; but the lower part of one side, and the bottom, are to be left loose so that a person can get in by stooping. This is clearly illustrated. During a raid the blanket should be wetted.

The windows must be specially protected against breakage by blast or splinters. We are recommended to gum transparent wrapping material inside the windows, though we are warned that the moisture-proof wrapping material used for food packets requires a special cellulose varnish to stick it on. Enterprising firms are already issuing rolls of suitable stuff.

For the benefit of those who cannot obtain these materials I would personally remark that in Madrid most large window-panes were strengthened by a criss-cross arrangement of stout paper strips pasted onto them. This seemed to give a good deal of protection against the blast from bombs falling some distance away. For those who can afford them the Government recommends a barricade of sandbags full of earth outside the window.

How far are these precautions effective? In 1937 a committee of the Cambridge Scientists' Anti-War Group published a book[1] in which it was stated that no ordinary room is anywhere near gas-proof. As I propose to criticize this book to some extent, I

[1] *The Protection of the Public from Aerial Attack.*

should like to begin by saying that in my opinion every fact recorded in it is entirely reliable, and that the experiments were well planned and carefully carried out. The method employed was to liberate carbon dioxide in a room, and to see how quickly it leaked out. This method was criticized by Mr. Geoffrey Lloyd M.P. in the House of Commons. After a false statement about the authors which would probably have been a slander had it been made outside Parliament, he went on to say, "These scientists did not measure the amount of gas which leaked into a room, but they measured the amount of gas which leaked out of a room, and then they tried to deduce by theoretical methods how much gas would have leaked into the room. I am advised by the Government's technical advisers that this procedure naturally led to important fallacies."

NO! only 1 external wall.

Let us examine this statement. The amount of gas which leaks into a room in a given time is exactly the same as the amount which leaks out, save for small corrections due to changes of temperature, pressure, and humidity, and small volume changes when oxygen is used up for breathing or burning. For suppose all the air in a room leaked out, and was replaced, not by the same amount of air, but by one per cent less, the pressure on the walls and windows would be increased by one hundredth of an atmosphere. The pressure on a 2 ft. × 5 ft. window would be 216 lbs., or 15st. 6 lbs.

The abstruse and intricate theory which the Cambridge scientists used is embodied in such equations as: 20 cubic feet (inwards) = 20 cubic feet (outwards).

WRONG! ∴ GAS LEAKS INTO 1 WALL (OUTER) OF ROOM, BUT LEAKS OUT OF ALL 4 WALLS!!!

It would appear that such abstract reasoning is beyond the grasp of His Majesty's Ministers. I do not for one moment believe that the technical advisers of the Government had the faintest doubt as to the validity of these experiments. Mr. Lloyd doubtless went on the principle

"That is enough to satisfy the Senate,"

and apparently it was enough. But such an answer shows that the standard of veracity of Ministers on scientific matters has not improved since the Home Secretary, defending the Government for not preventing the importation of fat into Germany, informed the house during the Great War that the production of glycerine from fat was a recent discovery, whereas it was actually made in 1779. The Honourable Gentleman scored his point, and some thousands of British soldiers died, as some thousands of British civilians will die for a similar reason in a future war. In case this is construed as an attack on Parliamentary Government, I may add that things are at least as bad in Germany, and worse in Italy, where criticism is treason.

The rate at which air leaks out of (and therefore into) houses was first investigated by Pettenkofer[1] in 1858. Between 1897 and 1902 a large number of experiments were made by J. S. Haldane on this question, in connection with poisoning by lighting gas,[2] and the ventilation of factories and workshops.[3] They were made with coal gas from burners and with

[1] *Ueber der Luftwechsel in Wohngebaüden* (Munich).

[2] *Report of Departmental Committee on carburetted water gas*, 1898.

[3] *Report of Departmental Committee on Ventilation of Factories and Workshops*, 1902.

more plausible for mustard gas. But I know of no evidence for it. And if it is true for mustard gas, the gas would possibly leak out gradually and cause chronic illness such as was common in mustard-gas factories.

The real criticism is as follows. It is unlikely that there would be a lethal concentration of gas out of doors for a long period. The wind carries gas away, and in cities there are vertical air currents even in calm weather. If many tons of bombs could be dropped in the same small area either at once or in succession this would not be so. But given any sort of defence bombs will be dropped more or less at random.

Suppose we had out of doors during 10 minutes a phosgene concentration of one part in 10,000, which would be fatal in a few breaths to people in the street, the concentration inside would never rise as high as $\frac{1}{15}$ of this value[1] if the leakage time were $2\frac{1}{2}$ hours, which is rather low. However, after the gas had cleared away from the street some would remain in the gas-proof room, just because it was gas-proof. So it would be an important part of the duty of air-raid wardens to see that gas-proof rooms are ventilated once a gas raid is over.

However, the above calculations are theoretical. More convincing in certain respects are the experiments performed "by the Chemical Defence Research Department under the aegis[2] of a special Sub-Committee of the Chemical Defence Committee" and published on December 31st, 1937. The house was sheltered by

[1] Since 10 minutes is $\frac{1}{15}$ of $2\frac{1}{2}$ hours. See Appendix III.

[2] The aegis was a shield used by the goddess Athene, or Minerva, when fighting Titans. It was made of goat-skin, and, like the types of shelter officially recommended, would be of little value against modern weapons.

"Experiments in Anti-Gas Protection of Houses", Home Office White Paper Circular, 31 Dec. 1937

trees, and therefore the wind was less than in open country. In one experiment a ton of chlorine was released 20 yards to the windward side of the house over a period of 40 minutes. Chlorine is about one-fifth as poisonous as phosgene. The gas penetrated into a room with shut doors and windows, but a fire on the hearth. After about seven minutes the men in it had to put on their respirators.

In a corresponding experiment in a gas-protected room animals were unaffected by double this amount of chlorine, whilst others in unprotected rooms were killed. Men in the protected room smelt the gas, and put on civilian respirators, which gave them complete protection.

Mustard liquid was first placed on shallow trays round the house, and then sprayed for an hour into the air to windward of it. Animals outside were badly affected. Of those in an unprotected room none were seriously harmed. Those in a "gas protected" room remained normal, and the amount of mustard gas in it was measured by chemical methods. It was found to be so small that a man could have remained in it for 20 hours without harm, even if unprotected by a respirator.

"Tear gas" in large amounts was sprayed into the air. It only penetrated an unprotected room very gradually, so that men in it did not need to put on respirators for 13 minutes. Arsenical smoke penetrated the unprotected room to such an extent that respirators were needed, though the civilian respirator gave protection. It penetrated the protected room to an extent which caused some irritation, so that respirators were finally put on.

opinion outside behind it." One would have supposed that after this he would have informed the public as to these plans, and asked it if it approved. But he did not do so. After all he has reason to be shy of "a general body of public opinion." He has already resigned office once as a result of the verdict of public opinion upon his activities.

Instead, he has "handed the baby" to a committee of four members of Parliament under the chairmanship of Sir John Anderson, representing the Scottish Universities, and formerly Governor of Bengal. We shall see what are the kinds of questions which they will have to decide.

Mr. Geoffrey Lloyd, M.P., the Under-Secretary for the Home Office, stated[1] that the evacuation of large numbers of people from London was not difficult if the actual technical decision that the evacuation was to take place at a given time was taken in time. In other words if Goering is kind enough not to attack us when we are most vulnerable, everything will be grand. "The Home Office had gone into the question with the railway companies, and had worked it out in detail. The time-tables had been worked out on a basis that 3,500,000 people could be moved 50 miles out of London or beyond by railway in 72 hours. . . . On the other hand they had considered what would be the position if the railway terminals and railways were damaged, and they would have to fall back on road transport. The Home Office had consulted the London Passenger Transport Board about the collection of refugees from London and their radial distribution at some distribution centres, and they knew something

[1] *Times*, June 2nd, 1938.

Secondly, as long as we have no adequate shelters the Labour Party, and other groups who are fundamentally opposed to vast war preparations, will be in a dangerous dilemma. At the present time the Labour Party dare not oppose expenditure on bombing aeroplanes in any effective way because if they did the National Government propagandists would say that they were leaving the country defenceless. And some members of the Labour Party may genuinely believe this. Actually the exact opposite is true. In the words of Mr. Duff-Cooper,[1] "We are no more prepared than we are as individuals against murder." And we shall be no more prepared for anything but counter-murder if we have 10,000 bombing aeroplanes. Hence until we can get underground we shall always be at the mercy of the militarists who demand more offensive weapons. This fact is perfectly well-known to the militarists, and is no doubt one reason for the refusal of our Government to undertake adequate defensive measures.

Yet from the point of view of any patriot, whether or not he is a lover of peace, the country is largely undefended against air attack until shelters are provided. To build an air fleet and no shelters is like building battleships with no armour, or sending an army into the field armed with the latest artillery and machine-guns, but with no spades for digging trenches.

At this point some pacifists will say that I have given my case away, and that I am really only a rather clever militarist trying to inveigle the parties of the Left into helping in preparations for the next war. I deny this. Pacifists can only win by persuasion, not

[1] See p. 79.

by force. At the present time they have not, as a matter of hard fact, been able to persuade the Labour Party to vote against rearmament. And they are unlikely to be able to persuade a majority of voters that the present British rearmament programme is wrong until it is generally realized that there is a method of protecting our people against air raids other than the threat of reprisals. Until we have a system of bomb-proof shelters it is inevitable that many people will believe Earl Baldwin's words, spoken in the House of Commons on November 10th, 1932, "I think it is well for the man in the street to realize that there is no power on earth that can protect him from being bombed. Whatever people may tell him, the bomber will always get through. . . . The only defence is in offence, which means you have to kill more women and children quickly if you want to save yourselves."

It has been one of the chief aims of this book to show that Earl Baldwin's statement is not only morally wrong, but technically wrong. Lovers of peace often make the disastrous mistake of refusing to study the technique of war because they regard it as wicked and disgusting. This is as if a surgeon refused to study cancer because it is a horrible disease.

The same sentimental objection will be brought against my proposals. Some readers will say that they would rather die than go back to the days of the cave men. The answer is that we are living in an age where morality, at least in international affairs, has fallen to a level which the cave men would very probably have condemned. If we build the shelters which I propose we shall very probably never need to use them.

If we do not do so we may very well find ourselves cowering in trenches and cellars which give us no protection against direct hits.

Once we have got rid of the burden of fear which hangs over us at present, the pacifist arguments will find a far readier hearing. And that, of course, is one reason why our militarists refuse to give us the shelters which we need.

Certain pacifist writers are severely to blame for our present terror of air raids. They have given quite exaggerated accounts of what is likely to happen. I have given actual and probable figures in Chapter II. Frightened people have not the courage needed to disarm, or even to think clearly about disarmament. Fear does not generate reason, but hatred. What Browning[1] wrote about Verona six centuries ago is substantially true of Europe today.

"Fear had long since taken root
In every breast, and now these crushed its fruit,
The ripe hate, like a wine; to note the way
It worked while each grew drunk! Men grave and grey
Stood with shut eyelids, rocking to and fro,
Letting the silent luxury trickle slow
About the hollows where a heart should be;
But the young gulped with a delirious glee
Some foretaste of their first debauch in blood."

I wish that every lover of peace would read this passage before quoting Earl Baldwin's statement that "the bomber always gets through." For we too are hardly likely to avoid hate so long as we cannot avoid fear.

[1] "Sordello," Book I.

If we in Britain dig shelters, the other nations will be bound to follow suit. And if this occurs the bombing aeroplane will become an ineffective weapon for the terrorization of civilians, even if it is kept for use in war as a kind of long-range artillery to harass transport behind the line of battle or to destroy munition factories.

We could whole-heartedly welcome measures of this kind in foreign countries. I will go so far as to say that Britain would actually be safer if every German city had bomb-proof shelters for its whole population. It would no longer be possible to frighten the German people into supporting an extreme form of militarism by the threat of bombardment by French, Russian, or British aeroplanes. And the cost of bomb-proof shelters, in Germany as in England, would to a considerable extent come from funds which would otherwise be devoted to making bombing aeroplanes. For it is fairly obvious that the finances of every European state are already strained to the breaking point. A. R. P. can mean Air Raid Precautions or Astronomical Rearmament Profits. It cannot mean both.

The cost of shelters will no doubt be considerable, even if, as I believe, it will only be about a quarter of what we are to spend on offensive rearmament. The sum in question could have been spent on rehousing the people if we had elected a Government which was willing to support international law. But it will not be recurrent expenditure, whereas the bombers which we are building today will be out-of-date in five years and wholly useless in ten. So long as we are frightened of enemy bombers we shall go

on building them ourselves, and any serious expenditure on social reconstruction will become more and more impossible.

There is a way out of this apparently hopeless situation, and that way is not by individual action. We are all parts of society. We cannot escape from it. If society is bad, we cannot help being bad. The only ultimate way out lies in a thorough-going reconstruction of society. But a necessary and indispensable preliminary to this is collective action to safeguard our lives from the menace of air raids, a menace which is generating such terror as to destroy our national sanity.

For this reason I believe that pacifists should collectively agitate for effective shelters. And individually, by becoming Air Raid Wardens, they should help to transform the Air Raid Services from the propagandist bodies which they are in some areas into genuine life-saving organizations.

So long as civilian populations are unprotected, criminal States will continue to murder the citizens of their weaker neighbours and to blackmail the stronger. By ending this possibility we can help to bring about a state of affairs where international relations rest on law rather than force, on reason rather than terror.

 MUSTARD DROPS:

infected. The skin burns are never fatal, and most cases are completely cured in a few months.

The eyes are particularly sensitive, and become extremely inflamed and painful. Nevertheless, only 10 cases out of 160,000 British casualties were partially and four totally blinded. A few others became blind later on as the result of injury to their eyes by mustard gas.

The main danger is to the wind-pipe and lungs. The gas causes bronchitis and broncho-pneumonia which are often fatal. The maximum mortality occurs on the fourth day, but those cases who survive a fortnight very rarely die, though a few are permanently affected.

Individuals vary greatly in their susceptibility to mustard gas. Some men blister if their skin is exposed for five seconds to air saturated with it. Others do not do so after five minutes. Negroes are particularly resistant. All volunteers for air raid precaution work should be tested for susceptibility. It would be folly to place a susceptible man in charge of decontamination work. So far this obvious precaution does not seem to have been taken in Britain.

It must be emphasized that against an unprotected population such as that of Abyssinia mustard gas is a cruel and terrible weapon. But against one protected with gas masks it is the most humane so far invented. Of 113,764 British casualties from gas in 1918 only 2,672, or 2.3 per cent (1 in 43) died, and about the same proportion were invalided for over 6 months. The proportion killed and invalided by bullets and shells was vastly greater. About 25 per cent of those hit were killed.

Mustard liquid was generally mixed with about 20 per cent of some organic liquid of lower boiling point to enable it to evaporate more quickly. But even so, when spilt on the ground, it remained for days or even weeks, until it disappeared, either by evaporation or by chemical reaction with water. The concentration of the vapour in air which is saturated with it at 15° C. is only about 1 part in 15,000 by volume. In actual practice the concentration in air is always much less. However, 1 part in a million can do considerable damage in an hour, though it is probably rarely fatal.

Hence if people *immediately* leave a contaminated area, they are unlikely to be much hurt by exposure to the vapour for a minute or two. This will be possible if the air-raid wardens know their jobs and enjoy the confidence of the people entrusted to their care.

Lewisite has no smell when pure, but the impure substance has a smell of geraniums. The vapour irritates the nose and eyes at once, so it is easy to detect. A respirator gives complete protection to the eyes, but the skin can be blistered. The blisters are rather more painful than those of mustard gas.

Physical properties of a Gas-cloud. Every student of chemistry learns that a heavy gas such as chlorine can be poured from one vessel into another almost like water, whilst a light gas such as hydrogen rapidly rises. Now all the poisonous gases and vapours used in war are heavier than air, so it is thought that they would inevitably flood cellars and underground shelters, and that on the first floor of a house one would not be safe.

It is true that pure phosgene is about $3\frac{1}{2}$ times as heavy as air. So in the immediate neighbourhood of a big bomb burst it would tend to sink. But within a short time it would be mixed with many times its volume of air. Now air containing one part in 10,000 of phosgene is extremely poisonous. But its density exceeds that of air by only one part in 4,000. Now an increase of density of this amount is secured if air is cooled down one eighth of a degree Fahrenheit.

So once the gas has dispersed, the question where it will go depends on the wind, and on local air currents determined by temperature. If liberated from a bomb with no bursting charge of explosive it may be a little cooler than the air around it. The question whether or not it will penetrate a cellar will be settled mainly by the pre-existing air currents. This matter is dealt with in Chapter IV.

APPENDIX II

GAS-MASKS, AND GAS-PROOF BAGS FOR BABIES

THE EARLIEST GAS-MASKS made in 1915, relied on chemical means to stop chlorine, which was the first gas used. A cloth soaked with sodium phenate or various other compounds will stop chlorine on its way through. But it would not stop carbon monoxide, mustard gas, or many other gases. The terrible prospect arose that it would be necessary to devise a new chemical to stop each new gas. There would be a continual series of surprise attacks with different gases, each successful until a remedy was found, and each involving the death of thousands of men.

It is a most fortunate fact that the majority of vapours can be removed from air, not by chemical combination, but by a process called adsorption, which is non-specific. For example lime will stop an acid gas such as carbon dioxide, and woollen cloth soaked in acid will stop an alkaline gas such as ammonia. No single chemical will combine with both.

But charcoal, silica, and various other substances, when properly prepared, will take up vapours of different chemical types. The molecules form a very thin liquid layer on the surface of the adsorbent, as indeed they do on glass or metals. But charcoal is full of pores and has an enormous surface per unit of weight; so it can take up a great deal of gas.

The main characteristic in a vapour which renders it adsorbable is that it should be the vapour of a liquid with a high boiling point. Thus carbon monoxide boils at–190° C, and is hardly adsorbed at all. Phosgene boils at 8° C and is fairly easily adsorbed. Mustard gas boils at 217° C and is very easily adsorbed indeed. This has a lucky consequence. It is quite sure that there are no unknown poisonous gases with a boiling point as low as that of carbon monoxide. For only a substance with very small molecules can have so low a boiling point. And chemists have made all the possible types of very small molecules. It is unlikely that there are any unknown poisonous gases with as low a boiling point as phosgene, though it is just possible. But if there are they will probably be stopped by charcoal. There may very possibly be some vapours of high boiling point more poisonous than mustard gas. But if so I am prepared to bet a thousand to one that charcoal will stop them all.

So activated charcoal will stop all poisonous gases except a few light ones such as carbon monoxide and hydrogen cyanide. And these latter are not very poisonous.

It is a curious fact that smokes are much harder to stop than gases. The reason is as follows. The molecules of a gas are moving very quickly, even when the gas as a whole is at rest. That is why such a small weight of gas occupies so much space. For example a molecule of phosgene at 60° F has an average speed of about 600 feet per second, though in an extremely zig-zag path, with many thousands of angles per inch; while a particle of an arsenical smoke has an average speed

of a fraction of an inch per second as a result of its collisions with air molecules. So on its way through a box full of fairly coarse grains of charcoal perhaps a tenth of an inch long a phosgene molecule is almost certain to hit one of them, whilst a smoke particle will probably not do so.

On the other hand most smoke particles, including those of the arsenical smokes, will stick to almost any solid which they touch. So smoke can best be filtered through a fabric with fine pores, such as felt or porous paper, or through a pad of cotton wool. So a respirator which is to stop gas and smoke contains both a filter for smoke and a box of charcoal for gas.

The charcoal offers no great resistance to air going through it, because the interstices between the grains are large. But a fabric does so if it is woven closely enough to stop smoke. Now if the same amount of air per minute is sucked through 5 square inches of felt the resistance will be 10 times as great as if it were sucked through 50 square inches. So the army respirators have a large area of smoke filter. The civilian respirators have a filter of smaller area which is not so efficient, and offers more resistance. Besides this, the military respirator has a corrugated rubber tube which is somewhat elastic, so that even a violent gasp for air does not create a great deal of suction.

In consequence a soldier can run in his respirator without too great a resistance to his breathing, and without creating so much suction (negative pressure) in his respirator as to make it likely to leak. The civilian

respirator is designed to give enough air for a man at rest or walking gently. But if the breathing is greatly increased three things happen. The resistance is unpleasant. The powerful suction may cause leakage. And the filter is less efficient against smoke when a large air current is drawn through it.

I am fairly confident in the efficiency of the civilian respirator in almost any gas concentration. It would not however be much use if a phosgene bomb actually burst inside a room. In this case the room would soon contain more phosgene than air, and instant flight would be the only possibility. But a person wearing it would be safe in a concentration of one part in 10,000 of phosgene, of which a very few breaths would otherwise be fatal. And against mustard gas it is even more efficient than against phosgene.

Its efficiency against smoke is less certain. The Cambridge Scientists' group have shown that it lets through tobacco smoke. On the other hand it seems to be proof against poisonous types of smoke except in very high concentrations. And it is worth remembering that although these smokes are most painful and demoralizing, they are not known to have killed anyone in the Great War. Still it is far more likely that a hostile nation has produced or will produce a smoke which will go through the civilian respirators than that they will produce a gas with this property.

The real danger to wearers of respirators is of quite a different character (see p. 105). It is that they will not fit adults, and that small children may find them intolerable. Both these possibilities can be dealt with by organization and training.

Handbooks.

No. 1	1937	Personal Protection Against Gas.
No. 2	1938 (2nd. ed.)	First Aid for Gas Casualties.
No. 3	1937	Medical Treatment for Gas Casualties.
No. 4	1937	Decontamination of Materials.
No. 5	To be published	Structural Precautions Against Bombs and Gas.
No. 6	1937	Air Raid Precautions in Factories and Business Premises.
No. 7	1937	Anti-Gas Precautions for Merchant Shipping.

Statutory Rules and Orders.

No. 251	1938	Air-Raid Precautions.
No. 252	1938	Air-Raid Precautions, England, Fire Schemes.
No. 253	1938	Air-Raid Precautions, London.

Other Publications.

Air-Raid Precautions Act, 1937.

Air-Raid Precautions Act, 1937, Air Raid General Precautions Scheme.

Air-Raid Precautions Act, 1937, Summary of Provisions.

The Protection of Your Home Against Air Raids.

Memorandum on Emergency Fire Brigade Organization.

An Atlas of Gas Poisoning.

HOME OFFICE

THE PROTECTION OF YOUR HOME AGAINST AIR RAIDS

READ THIS BOOK THROUGH

THEN

KEEP IT CAREFULLY

Why this book has been sent to you

If this country were ever at war the target of the enemy's bombers would be the staunchness of the people at home. We all hope and work to prevent war but, while there is risk of it, we cannot afford to neglect the duty of preparing ourselves and the country for such an emergency. This book is being sent out to help each householder to realise what he can do, if the need arises, to make his home and his household more safe against air attack.

The Home Office is working with the local authorities in preparing schemes for the protection of the civil population during an attack. But it is impossible to devise a scheme that will cover everybody unless each home and family play their part in doing what they can for themselves. In this duty to themselves they must count upon the help and advice of those who have undertaken the duty of advice and instruction.

If the emergency comes the country will look for her safety not only to her sailors and soldiers and airmen, but also to the organised courage and foresight of every household. It is for the volunteers in the air raid precautions services to help every household for this purpose, and in sending out this book I ask for their help.

Samuel Hoare

HOW TO CHOOSE A REFUGE-ROOM

Almost any room will serve as a refuge-room if it is soundly constructed, and if it is easy to reach and to get out of. Its windows should be as few and small as possible, preferably facing a building or blank wall, or a narrow street. If a ground floor room facing a wide street or a stretch of level open ground is chosen, the windows should if possible be specially protected (see pages 30 and 31). The stronger the walls, floor, and ceiling are, the better. Brick partition walls are better than lath and plaster, a concrete ceiling is better than a wooden one. An internal passage will form a very good refuge-room if it can be closed at both ends.

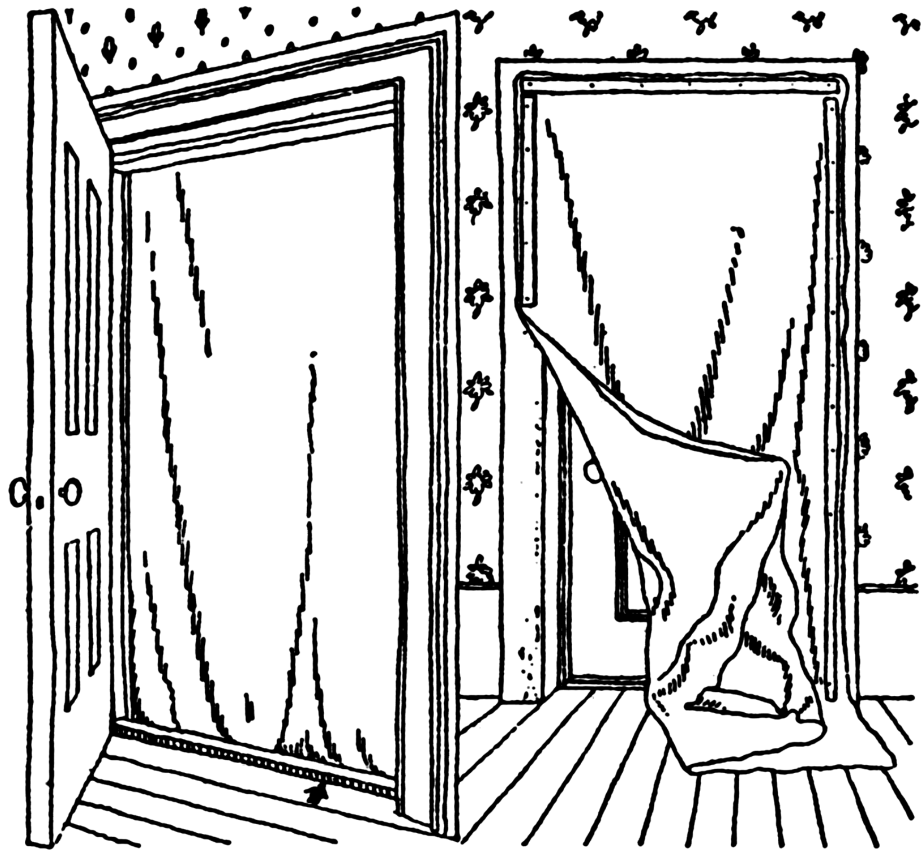
A cellar or basement is the best position for a refuge-room if it can be made reasonably gas-proof

The best floor for a refuge-room

A cellar or basement is the best place for a refuge-room if it can be made reasonably gas-proof and if there is no likelihood of its becoming flooded by a neighbouring river that may burst its banks, or by a burst water-main. If you have any doubt about the risk of flooding ask for advice from your local Council Offices.

Alternatively, any room on any floor below the top floor may be used. Top floors and attics should be avoided as they usually do not give sufficient protection overhead from small incendiary bombs. These small bombs would probably penetrate the roof but be stopped by the top floor, though they might burn through to the floor below if not quickly dealt with.

In a house with only two floors and without a cellar, choose a room on the ground floor so that you have protection overhead



How to seal up the door

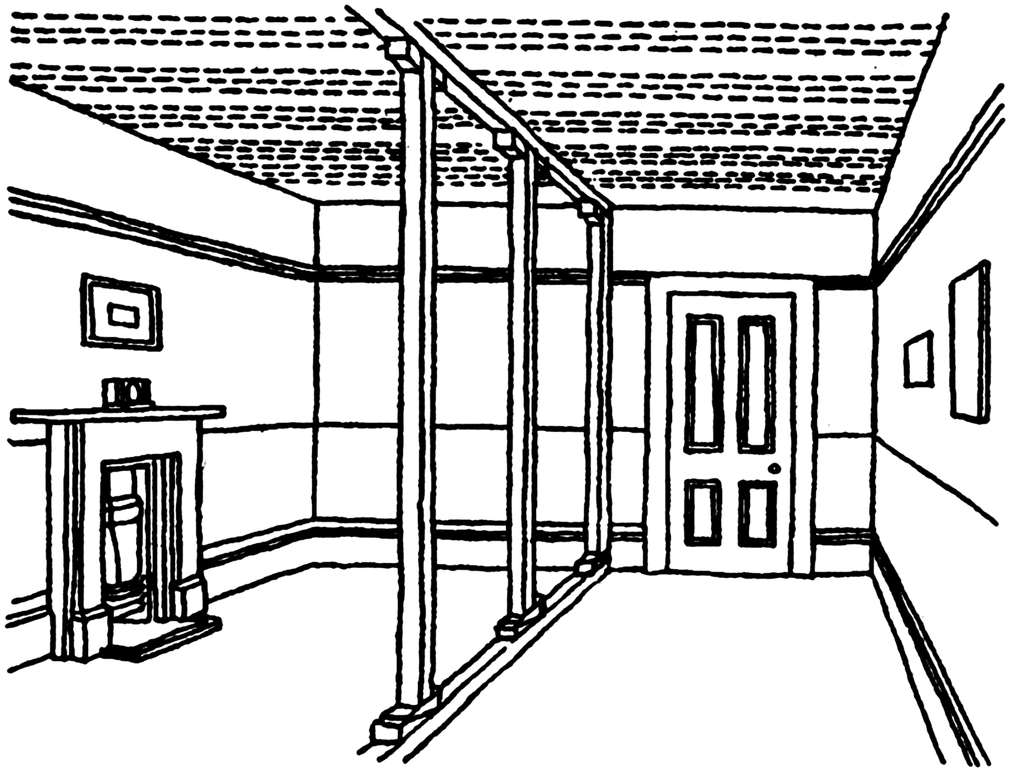
Doors which have to be opened and closed should be sealed against gas. This is how to do it.

Nail a piece of wood, padded with felt, to the floor so that the door, when closed, presses tightly against it. Take care not to nail this piece of wood on the wrong side of the door so that it cannot be opened. Strips of felt may also be nailed round the inside of the door to exclude draughts. Fix a blanket outside the door if the door opens inwards, or inside the door if the door opens outwards, with strips of wood. The top of the blanket should be fixed to the top of the door frame. One side of the blanket should be fastened down the whole length of the door frame, on the side where the hinges are, by means of a strip of wood nailed to the frame. The other side of the blanket should be secured not more than two feet down, so that a flap is left free for going in and out. Arrange the blanket so that at least 12 inches trails on the floor to stop air from blowing underneath it. See illustration above. If the blanket is kept damp during an air raid, it will give better protection.

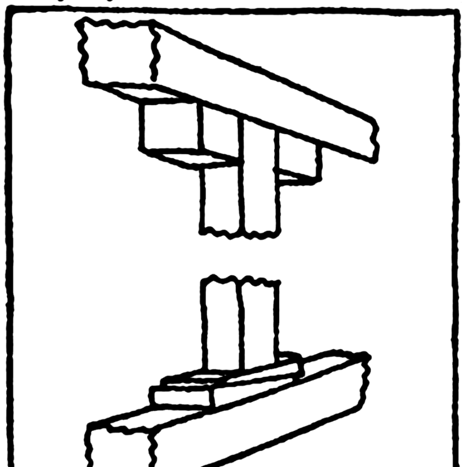
Strengthening the room

If your refuge-room is on the ground floor or in the basement, you can support the ceiling with wooden props as an additional protection. The illustration shows a way of doing this, but it would be best to take a builder's advice before setting to work. Stout posts or scaffold poles are placed upright, resting on a thick plank on the floor and supporting a stout piece of timber against the ceiling, at right angles to the ceiling joists, i.e. in the same direction as the floor boards above.

How to support a ceiling



The illustration below shows the detail of how to fix the props



The smaller illustration shows how the posts are held in position at the top by two blocks of wood on the ceiling beam. The posts are forced tight by two wedges at the foot, driven in opposite ways. Do not drive these wedges too violently, otherwise you may lift the ceiling and damage it. If the floor of your refuge-room is solid, such as you might find in a basement, you will not need a plank across the whole floor, but only a piece of wood a foot or so long under each prop.

How to deal with an incendiary bomb

You can tackle a small incendiary bomb yourself (better if you have someone to help you) if you will follow these directions. You will also be able to get proper instruction about it.

The bomb will burn fiercely for a minute or so, throwing out burning sparks, and afterwards less fiercely. It will set fire to anything inflammable within reach. You should try to deal with it before it has caused a big fire.

Before you can get close enough to do anything, you will probably have to cool down the room with water, preferably with a line of hose. (See page 20 for a simple hand pump.)

There are two ways of dealing with the bomb itself.

1 It can be controlled by means of the Stirrup Hand Pump (see page 20), with a *spray* of water which, although it does not extinguish the bomb, makes it burn out quickly and helps to prevent the fire spreading. Water must *not* be used on a bomb in any other way.

2 If it has fallen where you can get at it, it can be smothered with dry sand or earth. A bucket full of sand or earth is enough to cover and control a small bomb. The best method of applying it is by the Redhill sand container and scoop (see page 19); but a bucket will do if you have a long-handled shovel to use with it.

Immediately the bomb is smothered, shovel or scoop it into the sand container or bucket and take it out of doors. If a bucket is used, 2 or 3 inches of sand or earth must be kept in the bottom to prevent the bomb burning through.

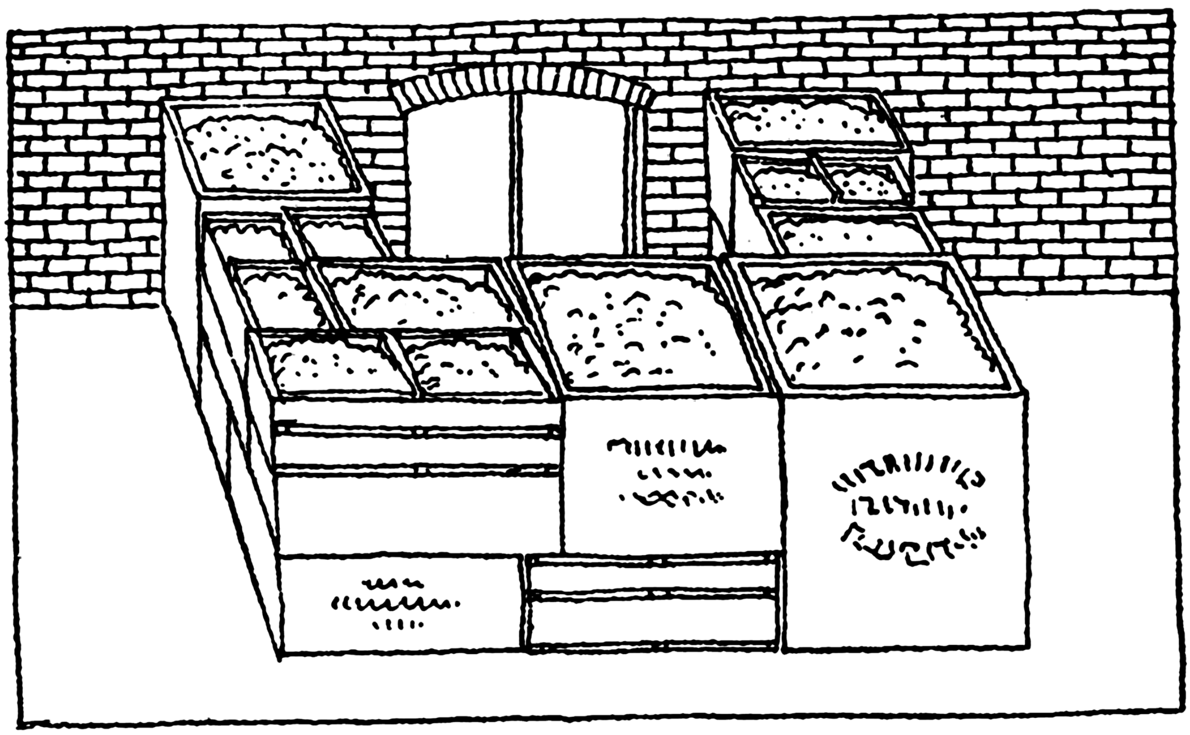
Remember that the bomb might burn through the floor before you have had time to remove it, and you might have to continue to deal with it on the floor below.

ACT PROMPTLY. PROMPT ACTION MAY BE THE MEANS OF SAVING LIVES. PROMPT ACTION WILL SAVE PROPERTY. PROMPT ACTION WILL PREVENT SERIOUS DAMAGE. PROMPT ACTION WILL DEFEAT THE OBJECT OF THE RAID.

EXTRA PRECAUTIONS AGAINST EXPLOSIVE BOMBS

TRENCHES. Instead of having a refuge-room in your house, you can, if you have a garden, build a dug-out or a trench. A trench provides excellent protection against the effects of a bursting bomb, and is simple to construct. Full instructions will be given in another book which you will be able to buy. Your air raid wardens will also be able to advise.

SANDBAGS. Sandbags outside are the best protection if your walls are not thick enough to resist splinters. Do not rely on a wall keeping out splinters unless it is more than a foot thick. Sandbags are also the best protection for window openings. If you can completely close the window opening with a wall of sandbags you will prevent the glass being broken by the blast of an explosion, as well as keeping out splinters. But the window must still be sealed inside against gas.



A basement window protected by boxes of earth

Any bags or sacks, including paper sacks such as are used for cement, will do for sandbags.

ALL persons involved in accidents suffer from shock, whether or not they suffer physical injury. Shock is a disturbance of the nervous system. It varies in its severity. The signs of shock are faintness, paleness, weak pulse, and weak breathing.

TREATMENT OF SHOCK

1 Place the patient flat on his back on a bed or a rug or on cushions. If you think a bone may be broken do not move the patient more than can be helped.

2 Loosen the clothing at the neck, chest and waist to make the breathing freer.

3 Cover the patient warmly with rugs and blankets. In cases of shock the body loses heat. A hot-water bottle is helpful, but take care that it does not lie in contact with the skin.

4 Give hot drinks. If you cannot make hot drinks, give cold water *in sips*. But only if the patient is conscious and able to swallow.

5 Soothe the patient by speaking reassuring words in a calm voice and in a confident way.

TREATMENT OF WOUNDS

The first thing to do is to stop the bleeding and to keep the wound clean. This can be done by covering it with a clean dressing bound on tightly. Do not touch a wound with your fingers because of the risk of poisoning from dirt. Treat the patient for shock in addition to attending to the wound, because the loss of blood, if the wound is serious, and the pain do in themselves cause shock.

WOUNDS IN THE HEAD AND BODY

1 Cover the wound with a clean folded handkerchief or a double layer of dry lint.

2 Apply another handkerchief or a layer of cotton wool as a pad to distribute the pressure over the wound.

3 Tie the dressing in position with a bandage, a strip of linen, or a necktie. This can be done quite firmly, unless there is any foreign body, especially glass, in the wound, or unless the bone is broken. In this case the dressing should be tied on lightly.

4 Treat the patient for shock.

- Basic decontamination procedures are generally the same no matter what the agent. Thorough scrubbing with large amounts of warm soapy water or a mixture of 10 parts water to 1 part bleach (10:1) will greatly reduce the possibility of absorbing an agent through the skin.

Sealing a Room

- Close all windows, doors, and shutters.
- Seal all cracks around window and door frames with wide tape.
- Cover windows and exterior doors with plastic sheets (6 mil minimum) and seal with pressure- sensitive adhesive tape. (This provides a second barrier should the window break or leak).
- Seal all openings in windows and doors (including keyholes) and any cracks with cotton wool or wet rags and duct tape. A water-soaked cloth should be used to seal gaps under doors.
- Shut down all window and central air and heating units.

Suggested Safehaven Equipment

- Protective equipment—biological/chemical rated gas masks, if available; waterproof clothing including long-sleeved shirts, long pants, raincoats, boots, and rubber gloves.
- Food and water—a 3-day supply.
- Emergency equipment—flashlights, battery-operated radio, extra batteries, can or bottle opener, knife and scissors, first aid kit, fire extinguisher, etc.
- Most chemical and biological agents that present an inhalation hazard will break down fairly rapidly when exposed to the sun, diluted with water, or dissipated in high winds.

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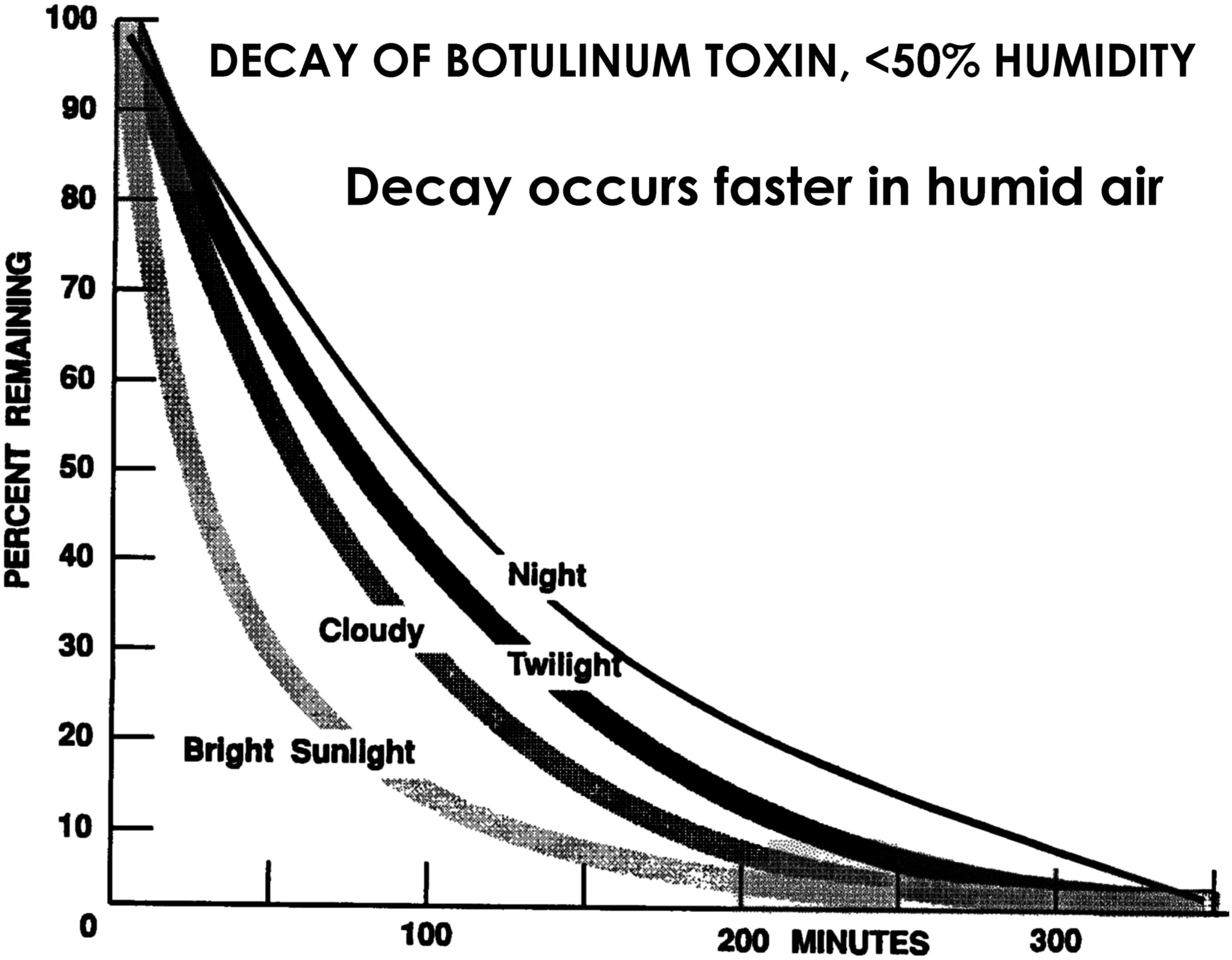
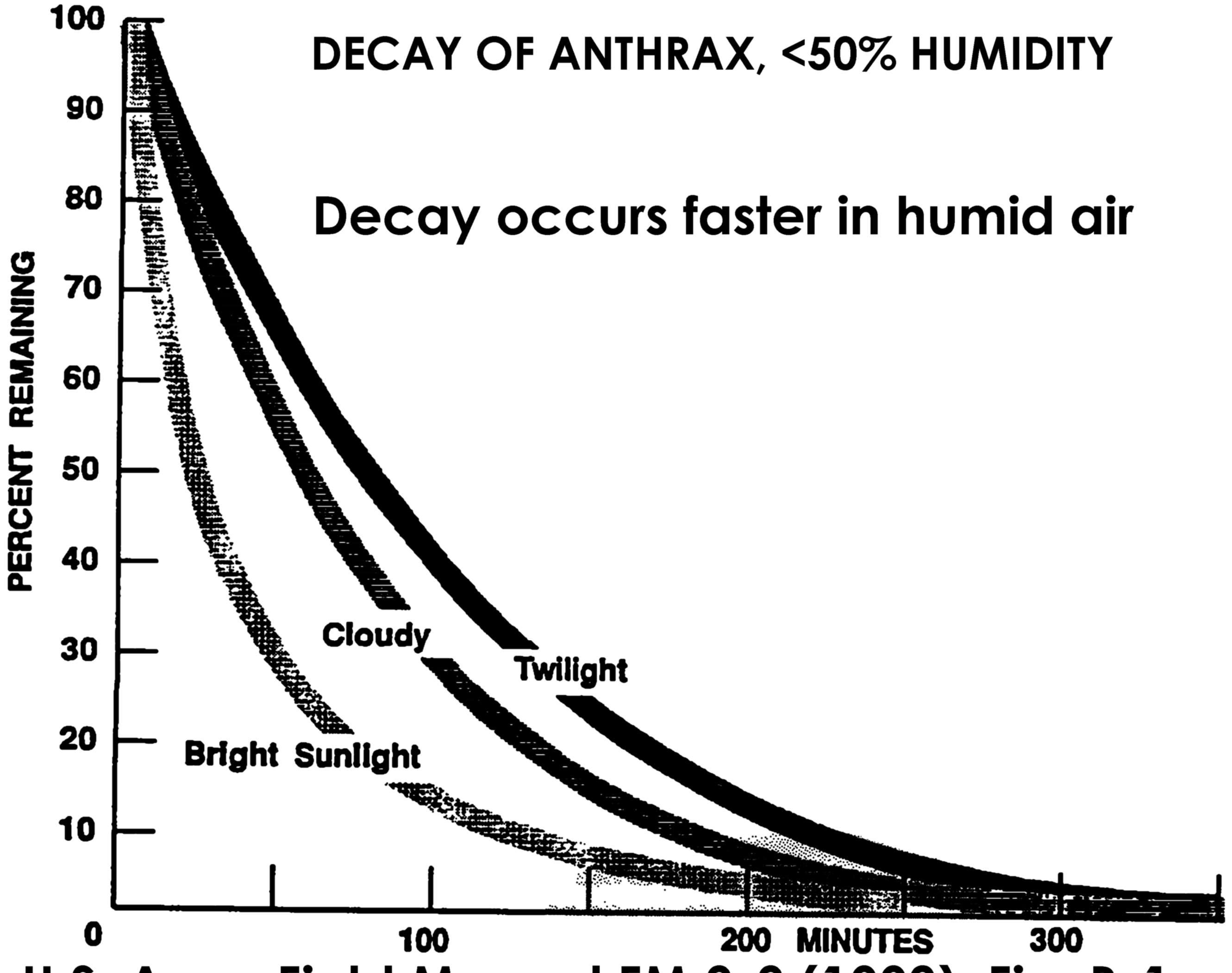
Responding to a Biological or Chemical Threat IN THE UNITED STATES

In 1995, the Aum Shinrikyo, a Japanese religious cult, launched a large-scale chemical attack on the Tokyo subway system. The attack focused on four stations using Sarin gas, a potent chemical warfare nerve agent. Twelve people were killed but the attack fell far short of the apparent objective to inflict thousands of casualties. Subsequent investigation by authorities revealed that the cult had previously conducted several unsuccessful attacks against a variety of targets using other chemical agents and the biological agents botulism toxin and anthrax.

More recently, the incidents of anthrax contamination in the United States served to illustrate the viability of this type of terrorist threat. Again, the attacks fell short of mass casualties, but some deaths did occur and the fear and disruption caused by a few positive anthrax findings were crippling. The U.S. Government continues working to meet the potential consequences of such attacks.



U.S. Army Field Manual FM 3-3 (1992), Fig. B-3.



U.S. Army Field Manual FM 3-3 (1992), Fig. B-1.

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Energy Division

Will Duct Tape and Plastic Really Work? Issues Related To Expedient Shelter-In-Place

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Expedient sheltering involves the use of common materials to enhance the safety of a room inside a building against the impacts of a chemical plume. The central premise behind taping and sealing with duct tape and plastic is to reduce airflow into a room. Vapors penetrate into a room through cracks and openings in the walls, floors and ceilings, around doors and windows, and through openings for ducts, light fixtures, fans, pipes, electrical outlets, chimneys, door handles, and locks. The goal of taping and sealing is to significantly reduce infiltration at these points.

Expedient sheltering was suggested by NATO (1983) using the term “ad-hoc shelter” to protect civilian populations from chemical warfare agent exposure. The concept was to use plastic sheeting to seal off a room by fashioning a simple airlock at the entrance to the room and sealing off doors, windows or louvered vents. The NATO guidelines also stressed the need for rapid exit from the ad-hoc shelter once the plume had passed to avoid further exposure (NATO 1983, p. 143).

This strategy was further developed by the Israeli Civil Defense in the mid-1980s to protect the public against a chemical weapons attack (Yeshua 1990). The tape and seal strategy was in place when the Gulf War occurred in 1991 and received considerable media attention. The Israeli strategy was to have citizens prepare a “safe room” in their house or apartment with the use of weatherization techniques to permanently reduce infiltration. Citizens were also instructed to take expedient measures, such as sealing

doors and windows with plastic sheets, in the event of a chemical weapons attack. The use of plastic over a window was developed to reduce air infiltration and to provide a vapor barrier in the event of glass breakage from bomb explosions. A modification of the Israeli strategy was proposed for use in CSEPP (Sorensen 1988; Rogers et al. 1990).

Although vapors, aerosols, and liquids cannot permeate glass windows or door panes, the amount of possible air filtration through the seals of the panes into frames could be significant, especially if frames are wood or other substance subject to expansion and contraction. To adequately seal the frames with tape could be difficult or impractical. For this reason, it has been suggested that pieces of heavy plastic sheeting larger than the window be used to cover the entire window, including the inside framing, and sealed in place with duct or other appropriate adhesive tape applied to the surrounding wall.

Another possible strategy would be to use shrink-wrap plastic often used in weatherization efforts in older houses. Shrink-wrap commonly comes in a 6 mil (0.006-in.) thickness and is adhered around the frame with double-faced tape and then heated with a hair dryer to achieve a tight fit. This would likely be more expensive than plastic sheeting and would require greater time and effort to install. Because double-faced tape has not been challenged with chemical warfare agents, another option is to use duct tape to adhere shrink-wrap to the walls. Currently, we do not recommend using shrink-wrap plastics because of the lack of information on its suitability and performance.

3. WHY WERE THESE MATERIALS CHOSEN?

Duct tape and plastic sheeting (polyethylene) were chosen because of their ability to effectively reduce infiltration and for their resistance to permeation from chemical warfare agents.

3.1 DUCT TAPE PERMEABILITY

Work on the effectiveness of expedient protection against chemical warfare agent simulants was conducted as part of a study on chemical protective clothing materials (Pal et al. 1993). Materials included a variety of chemical resistant fabrics and duct tape of 10 mil (0.01-in.) thickness. The materials were subject to liquid challenges by the simulants DIMP (a GB simulant), DMMP (a VX simulant), MAL (an organoposphorous pesticide), and DBS (a mustard simulant). The authors note that simulants should behave similarly to live agents in permeating the materials; they also note that this should be confirmed with the unitary agents. The study concluded that "duct tape exhibits reasonable resistance to permeation by the 4 simulants, although its resistance to DIMP (210 min) and DMMP (210 min) is not as good as its resistance to MAL (>24 h) and DBS (> 7 h). Due to its wide availability, duct tape appears to be a useful expedient material to provide at least a temporary seal against permeation by the agents" (Pal et al. 1993, p. 140).

3.2 PLASTIC SHEETING PERMEABILITY

Tests of the permeability of plastic sheeting (polyethylene) challenged with live chemical warfare agents were conducted at the Chemical Defense Establishment in Porton Down, England in 1970 (NATO 1983, p. 133). Agents tested included H and VX, but not GB. Four types of polyethylene of varying thickness were tested: 2.5, 4, 10 and 20 mil (0.0025, 0.004 in., 0.01 in., and 0.02 in.). The results of these tests are shown in Table 1.

Table 1: Permeability of plastic sheeting to liquid agent

	Breakthrough time (h)	
Thickness	VX	H
0.0025	3	0.3
0.004	7	0.4
0.01	30	2
0.02	48	7

Source: NATO 1983, p. 136.

The data shows that at thickness of 10 mil or greater, the plastic sheeting provided a good barrier for withstanding liquid agent challenges, offering better protection against VX than for H. Because the greatest challenge is from a liquid agent, the time to permeate the sheeting will be longer for aerosols and still longer for vapors, but the exact relationship is unknown due to a lack of test data.

In Fig. 1 we plot the data in Table 1 to determine the nature of the relationship between thickness and breakthrough time. The data suggest a somewhat linear relationship, thus allowing some interpolation for various thickness of plastic sheeting. For reference, commercially available sheeting is typically sold at 0.7, 1, 1.2, 1.5, 2, .2.5, 3, 4, 6, and 10 mil. although thicker material is available (up to 100 mil). Plastic painter drop cloths are sold between 0.5 and 2 mil.

4. HOW HAVE THEY PERFORMED IN TESTS OR REAL EVENTS?

Although the “safe room” strategy was used in the many scud missile attacks against Israel in the Gulf War, no chemical agents were released during these attacks. Sheltering has been recommended as a protective action in several chemical releases in the United States and Canada. Some anecdotal information exists about sheltering effectiveness in those events, but no empirical studies of actual effectiveness in a real event have been conducted. Such data would be extremely difficult to capture. Two sets of experiments have been conducted on the effectiveness of in-place sheltering (Rogers et al. 1990; Blewett et al. 1996).

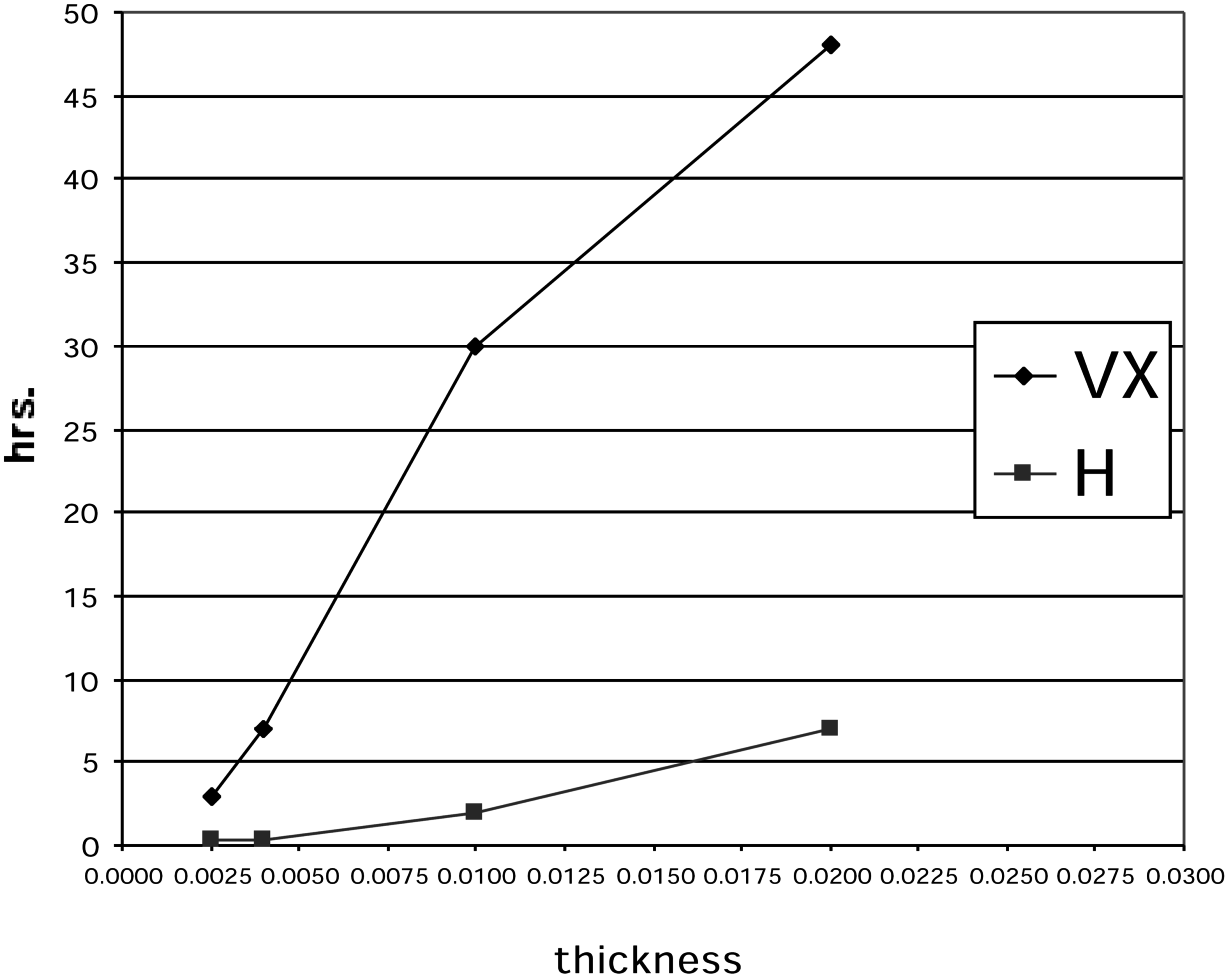

Fig. 1. Breakthrough as a function of the thickness of plastic sheeting.

The results of the two sets of experiments or trials using tracer gas methods provide some insight into the effectiveness of expedient sheltering. These trials were conducted in the vicinity of Oak Ridge, TN., in the late 1980s and Edgewood, MD in the mid 1990's. The Oak Ridge tests involved 12 single-family homes. The trials measured the air exchange for the whole house, the expedient room (mainly bathrooms) with a towel against the door, and the bathroom fully taped and sealed by a household member. Materials used included duct tape, flexible insulation cord, and plastic sheeting. In each test, subjects were given written instructions and checklists, but were left to make the decision how to seal the room.

Infiltration or air exchange is measured by the number of air changes per hour (ach). The average air exchange rate for the houses tested in the Oak Ridge trials was 0.45 ach. The bathrooms with a towel averaged only 0.94 ach. The fully sealed bathrooms averaged

0.33 ach, a reduction of 0.61 ach or 65% (0.61/0.94). One factor not assessed in the study was the air exchanged between the sealed room and the whole house versus the sealed room and the outside. If one assumes that the air exchanged by the room is mostly with the rest of the house, an added protection factor would be achieved because the contaminated air concentrations outside the house are reduced by mixing with air in the whole house and then reduced again in the expedient room. If it is assumed that most of the exchange is between the room and the outside, little added protection beyond that provided by the room would be achieved.

The tests in Edgewood, Maryland, involved 10 residential buildings and 2 mobile homes. Three types of rooms were tested: bathrooms with windows, windowless bathrooms, and walk-in closets. The expedient measures were applied by technicians, and the doors were taped from the outside of the room. A total of 36 trials were performed using different configurations of protection. The results (Table 2) show the air exchange rate for the whole house and for the room in which the expedient measure(s) was applied. The most aggressive strategy (Method 2) proved to be fairly effective, reducing average air exchange rates to between 0.15 and 0.21 ach.

Table 2: Results of Edgewood trials

Room and method	Average house ach	Average room ach
Bathroom—no expedient measures	0.29	0.27
Method 1: Bathroom—wet towel and taped vent	0.28	0.23
Method 2: Bathroom—door taped, plastic sheet on window, wet towel and taped vent	0.32	0.21
Windowless bathroom—no expedient measures	0.37	0.29
Method 1: Windowless bathroom—wet towel and taped vent	0.33	0.29
Method 2: Windowless bathroom—door taped, wet towel and taped vent	0.34	0.15
Walk in closet—no expedient measures	0.39	0.28
Method 1: Walk in closet—wet towel and taped vent	0.44	0.30
Method 2: Walk in closet—door taped, wet towel and taped vent	0.21	0.15

A good way of examining the numbers in the table is to compare the baseline case (door closed with no expedient protection) to the case with the greatest amount of expedient protection (Method 2). For the bathroom, the ach dropped from 0.27 to 0.21 (22%). For the windowless bathroom, the ach dropped from 0.29 to 0.15 (48%). For the closet, the ach dropped from 0.28 to 0.15 (46%).

The results of the two studies are consistent. Both studies showed a reduction of average air exchange rates from expedient protective measures. In some of the specific rooms tested such measures substantially reduced air infiltration into the sealed room when compared to the unsealed room. Infiltration was reduced in one trial by 90% in the

Oak Ridge study and by 57% in Edgewood study. In addition, fairly low air exchanges were achieved in some of the specific expedient room trials (0.11 ach in both studies). The effectiveness of individual trials varied. In the Oak Ridge study, the lowest reduction was 13% and highest air exchange rate was 0.58 ach. In the Edgewood study, the highest air exchange rate for the most aggressive strategy (Method 2) was 0.31 ach. The greater variability in the Oak Ridge data likely results from the variability in the way individuals implemented the taping and sealing, which was more uniform in the Edgewood study because taping was done in a consistent manner by a skilled technician.

5. TIMING OF EXPEDIENT SHELTER

In the ORNL study (Rogers et al. 1990), the time to implement the expedient protection was recorded. Overall times ranged between 3 and 44 min in total, with a mean of 19.8 min. The time to close up the house was relatively short, with a mean of 3.2 min with a range of 1 to 6 min. Times to tape and seal ranged between 2.3 and 38.6 min, with a mean of 16.7 min. These data are shown in Fig. 2.

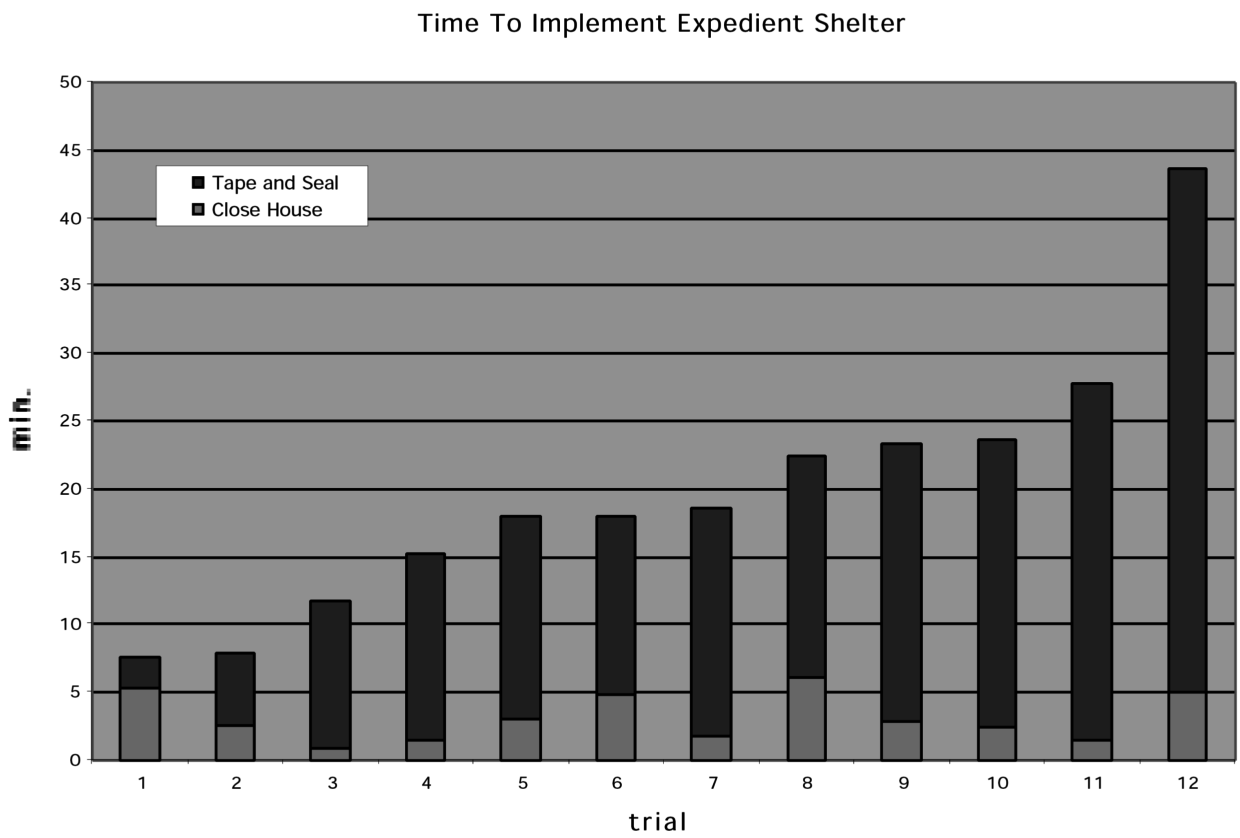

Fig. 2: Expedient shelter trial times.

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ORNL/TM-10423

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MARTIN MARIETTA

Technical Options for Protecting Civilians from Toxic Vapors and Gases

C. V. Chester

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Prepared for
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Aberdeen Proving Grounds, Maryland

OPERATED BY
MARTIN MARIETTA ENERGY SYSTEMS, INC.
FOR THE UNITED STATES
DEPARTMENT OF ENERGY

Table 1. Chemical Agent Toxic Properties[1]

Agent	Volatility (mg/m^3, 25°C)	Median Lethal Concentration X Time (mg/m^3 *min)		Median Incapacitation Concentration X Time
		Respiratory	Percutaneous	(mg/m^3 *min)
Chlorine (CL)	2.2×10^7	19,000	-	1,800
Phosgene (CG)	4×10^6	3,200	-	1,600
Hydrogen Cyanide (AC)	1×10^6	2,000-4,500	-	>2,000
Cyanogen Chloride (CK)	1×10^6	11,000	-	7,000
Sulfur Mustard (HD)[2]	920	1,500	10,000	200
Nitrogen Mustard (HN-1)	2,000	1,500	20,000	200
Lewisite (L)[2]	6,000	1,200-1,500	100,000	300
Mustard Lewisite (HL)	4,200	1,500	>10,000	200
Tabun (GA)[2]	610	400	40,000	300
Sarin (GB)[2]	22,000	100	15,000	35-75
Soman (GD)	3,900	100	1,000	35-75
VX[2]	10.5	100	1,000	50
Methyl Isocyanate		1500		

[1] Taken from U.S. Department of the Army (1975) and WHO (1970).

[2] Chemical agents in the stockpile to be destroyed in this program.

DISTANCE AND ATMOSPHERIC DISPERSION

As a toxic cloud moves downwind it mixes with ever increasing amounts of air, becoming larger and more dilute. Diffusion of the vapor vertically and at right angles to direction of motion reduces the exposure to someone standing in the path of the cloud. Diffusion forward and backwards along the direction of travel in general does not reduce the amount inhaled by someone in the path of the cloud.

The rate of vertical and lateral mixing of the toxic cloud with the surrounding air can vary enormously depending on weather conditions. A bright, sunshiny day promoting convection of the atmosphere close to the ground will cause rapid vertical mixing. A turbulent wind will promote lateral mixing. High windspeeds also reduce the time that a person is immersed in a passing cloud and directly reduces the amount they will inhale for given quantity going by. The worst conditions providing the greatest threat to people at the greatest distance downwind occur under conditions of light, steady winds, a clear night with cooling of the ground to cause vertical stability in the atmosphere and the existence of a temperature inversion not too far above the ground to trap the chemical close to the ground. Conditions very close to these were responsible for the large casualties at the Bhopal incident in India.

Figure 1 shows the downwind hazard from clouds of 1000 kilograms of each of several toxic gases moving at 1 meter per second (approx. 2 miles per hour) in a highly stable atmosphere (Pasquill type E). These conditions also assume an inversion at 750 meters. Calculations use the Army's D2PC code (Whitacre et al, 1986). The dependent variable in Fig. 1 is given as the protection factor offered by protective measures required to prevent 99 percent of the fatalities at each location downwind. For example for GB, to keep the dose down to 1 percent fatalities at 1 kilometer downwind, the population would have to have masks or other protection giving a protection factor of a little less than 700. The

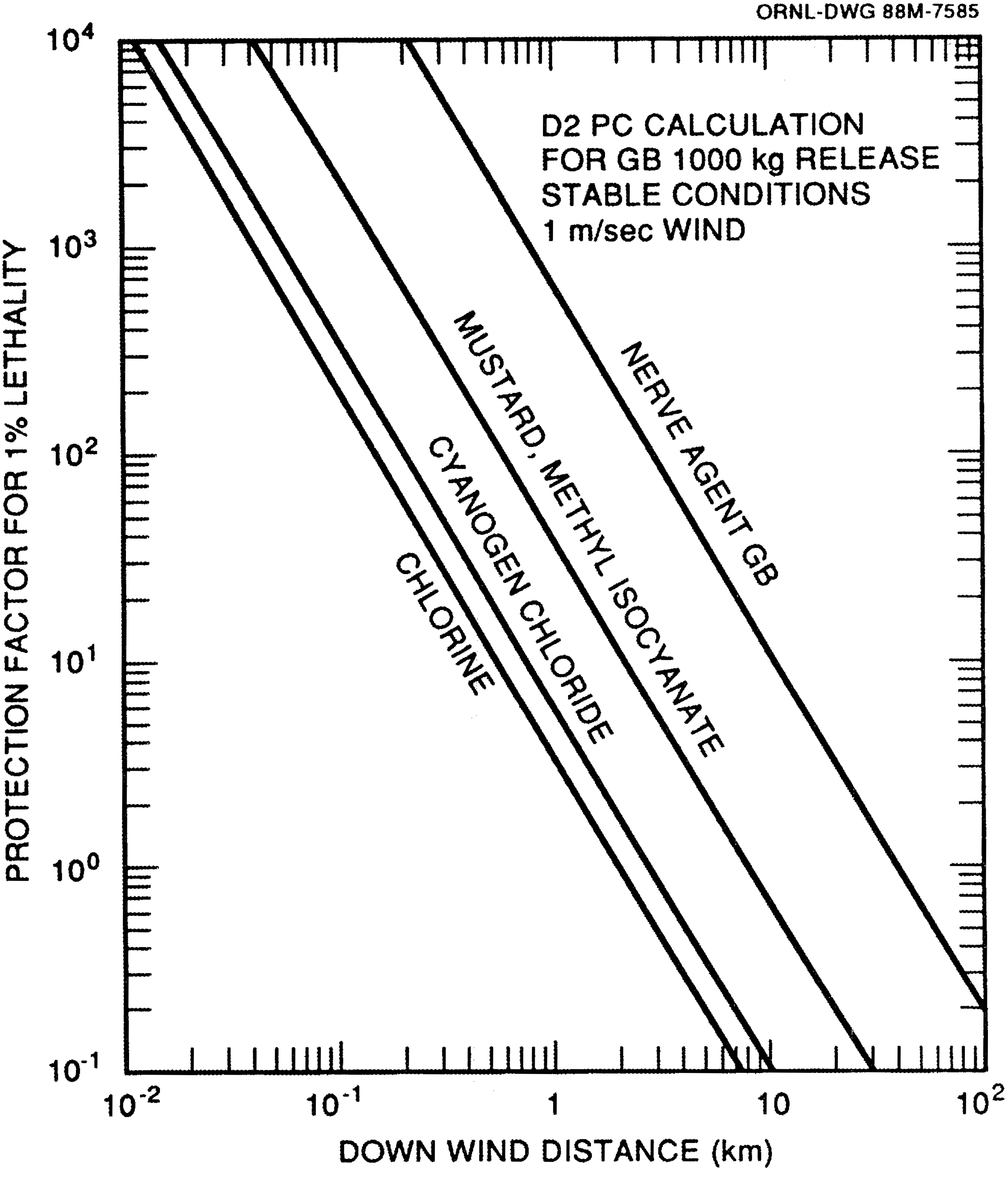

Fig. 1 Dose vs Downwind Distance for Some Very Toxic Gases

protection factor is the ratio of the dose people would get with no mask compared to what they would get if they were wearing a gas mask.

As can be seen from Fig. 1 the requirement for gas masks diminishes rapidly as one gets further away from the point of release of a quantity of agent. Under sunny conditions with a higher wind speed the requirement for protection would decrease even more rapidly. For the purposes of this study, these relatively pessimistic meteorological conditions (1.0 m/s. wind velocity, type E stability, inversion at 750 m) will be assumed in all cases.

EVACUATION

Evacuation is a way of increasing the distance between the population and a hazard and is the countermeasure to toxic chemical releases with which there is the most experience. Sorensen and his colleagues have reviewed the subject thoroughly (1987). It is very effective for slowly (few hours) developing hazards and in areas where emergency plans employing evacuation have been developed. Slowly developing chemical hazards can include a relatively small leak of a volatile toxic chemical, a large spill of a low volatility but highly toxic substance, or a progressive accident (e.g. fire) which doesn't at first cause release of toxic chemicals but has the potential of spreading to nearby equipment, tanks or drums containing toxics. Where small areas are threatened, evacuation can be quite effective.

Situations where taking shelter may be preferable to evacuating include quick release of small quantities of volatile toxic chemicals, or circumstances where an evacuation is likely to result in a traffic jam. This latter is a possibility where the area at risk is large, the population density is high, and the time available is short.

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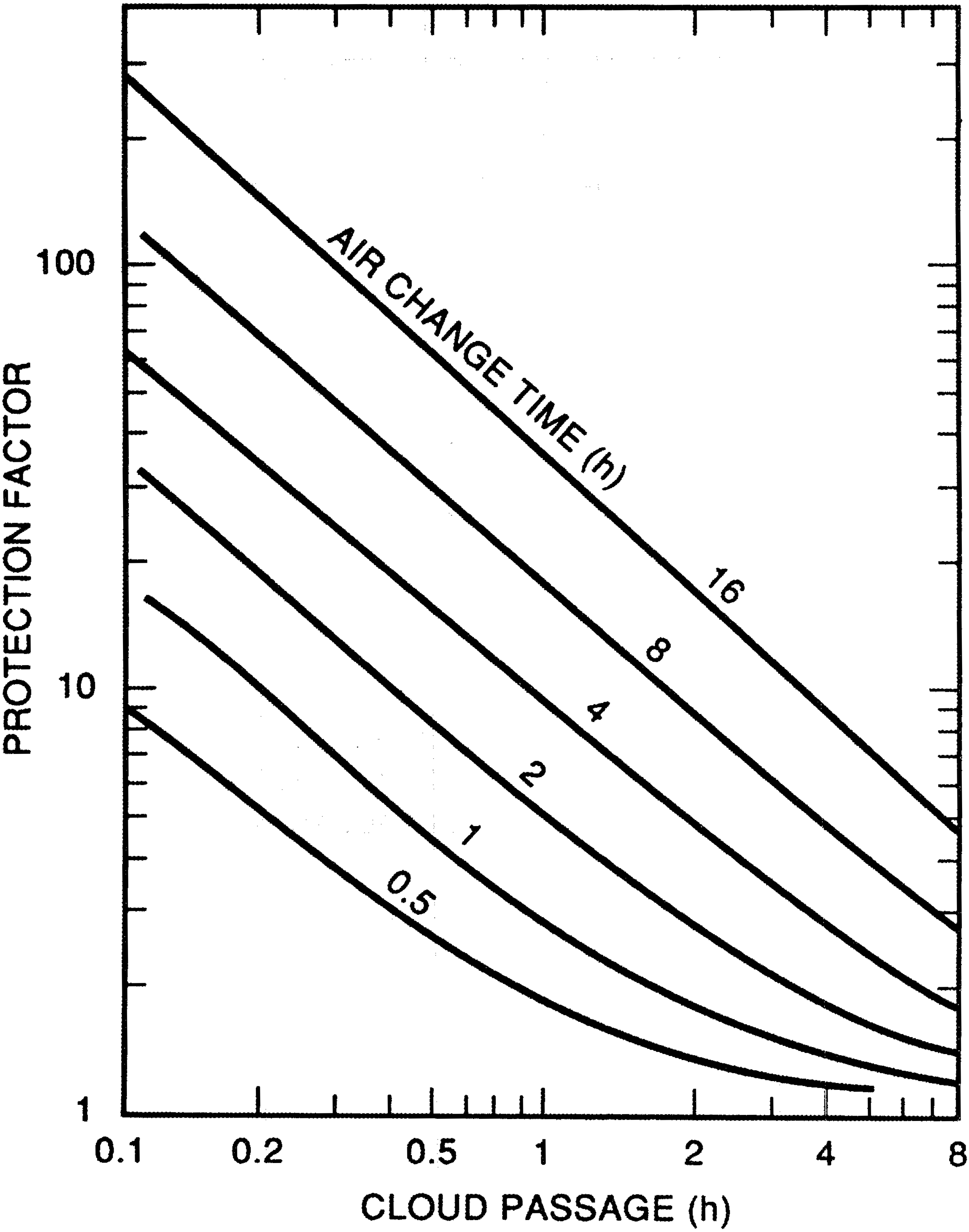

Fig. 2 Protection Factor of Leaky Enclosures

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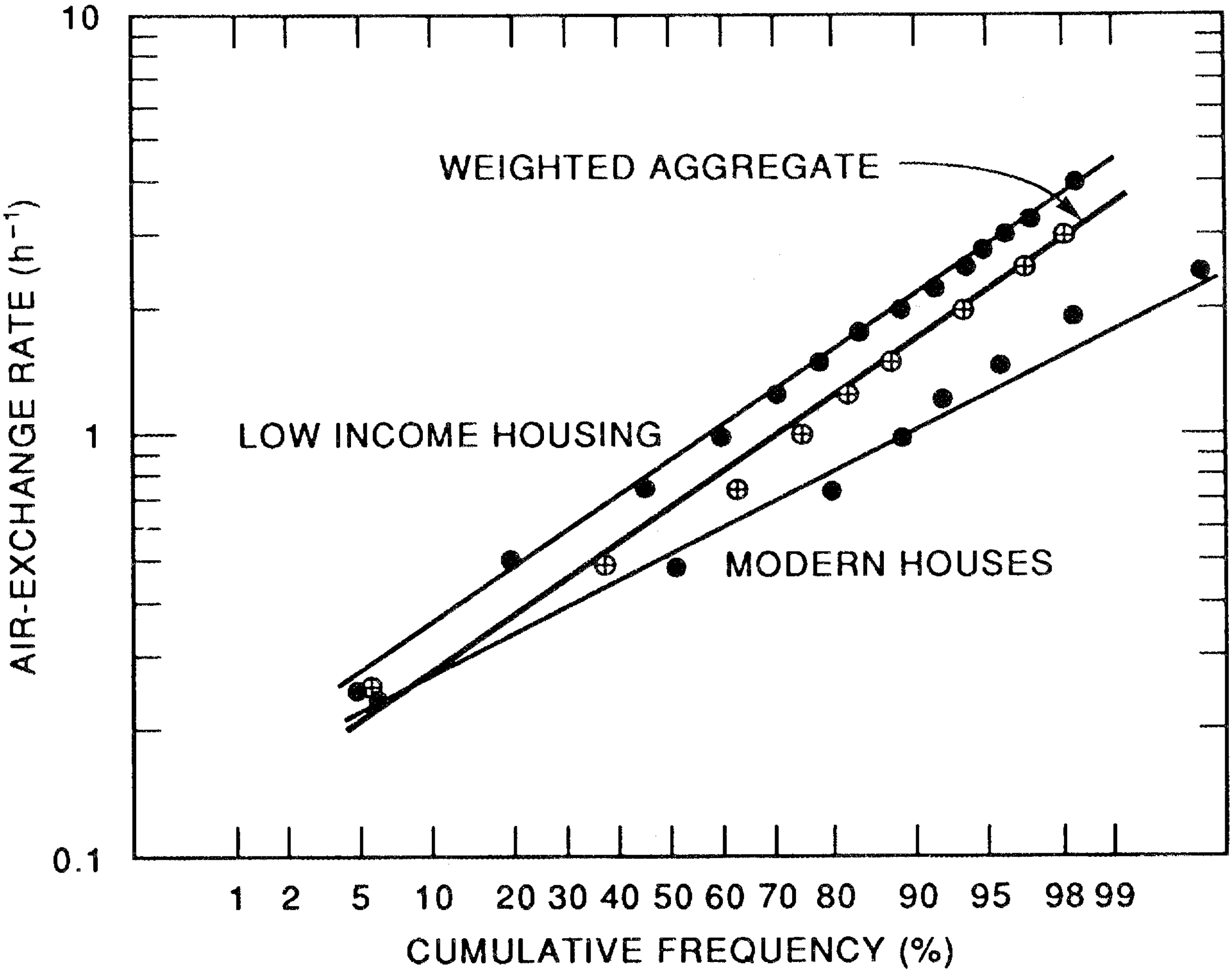

Fig. 3 Infiltration Rates of American Residences

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USAWC RESEARCH ELEMENT
(Research Paper)

What's Wrong With Gas Warfare?

by

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US Army War College
Carlisle Barracks, Pennsylvania
8 April 1966

Techniques for employment of war gases have not changed appreciably since World War I: volatile war gases are to be used for surprise effect (i.e., to establish a concentration in the target area before the enemy can mask); and to obtain casualties through poor discipline or defensive equipment by covering large areas and by massive dosages.[2] While these techniques remain valid, they should be limited to the attack of military targets that are far removed from civilian population centers. Examples of such targets are the Japanese island strongholds of World War II, Tarawa and Iwo Jima, and guerrilla areas in Vietnam where the insurgents are isolated and relatively invulnerable to bombing with high explosives. The reasons that current techniques for employment of gas will have infrequent application in modern warfare are:

(1) Unless the target is under close observation or there is excellent intelligence, the protective posture (availability of masks and special clothing) of the enemy will be unknown. The expected results for planning subsequent operations will be in doubt.

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[2]US Dept of the Army, Field Manual 3-10, p. 12.

(2) A sophisticated enemy has modern defensive equipment and can be protected in seconds, if not already protected at the time of the attack. Attempts to "beat" enemy personnel to their masks require large expenditure of war gases and corresponding concentration of delivery means. The risk involved in the exposure of delivery systems to enemy countermeasures is not worth the questionable results.

(3) The variability of surface winds preclude assurance as to where the gas cloud will travel. The military value of downwind drift of the cloud can be negated by automatic gas alarms and good communications. It is highly probable that many civilian casualties will be produced unintentionally because they are unlikely to have masks, ventilated shelters, alarms, and antidotes.

Since military targets in most areas of the world will be near civilian population centers, the primary application of volatile war gases must be as an integrated means of firepower. Volatile war gases should be integrated with high explosive ordnance to the extent that they are used simultaneously. The burst of the high explosive ordnance and gas shells or bombs will be completed instantaneously, destroying or damaging gas protective equipment. Subsequently the gas will spread over the area, achieving an effectiveness greater than if either HE or gas was used alone. The number of gas shells or bombs in the mixed ordnance should be kept small enough so that

lethal effects of the cloud will not extend beyond the target area. Gas used prior to high explosives will be dispersed by the HE detonations and thereby made ineffective. Gas can be used immediately after high explosives, but there must be no delay in the gas attack to permit the enemy to react (use defensive equipment) and lessen his difficult defense problem of simultaneously protecting himself against two widely different threats.

The simultaneous sequence of fires should be carried one step further for large-caliber direct-fire weapons used to attack fortifications and armored vehicles (e.g., recoilless rifles). For gas warfare these weapons should have a gas capsule as an integral part of the munition warhead. This composite munition would utilize its piercing capability to make a hole for the gas to follow through and enter the enclosure. The combined effects of such a munition would greatly increase the "probability of kill" and provide gas an anti-armor role.

Current concepts for the use of non-volatile war gases indicate that they are to be used to contaminate terrain, equipment, and materiel, and to produce casualties or the threat of casualties by their presence.[3] The use of non-volatile war gases to contaminate terrain (except in isolated areas or against an unsophisticated enemy) should be reconsidered. Modern armed forces are highly mobile: helicopters can airlift soldiers over gas obstacles

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[3] Ibid.

PUBLIC INFORMATION PROGRAM

A new national policy on gas warfare such as the one presented above can provide the necessary guidance for the people as to the importance of gas weapons and their role. The formulation of policy must precede or accompany any attempt to educate the public on gas warfare since "public knowledge of facts is not understanding until it can be set in the framework of policy and goals."[11]

Public resistance to a new policy may occur because of false impressions about gas warfare. Since the American people have considerable influence on adoption of policy, they must be provided objective information on gas warfare. As "Elihu Root...wrote... when policy on foreign affairs is largely dominated by the people, the danger lies in mistaken beliefs and emotions."[12]

The issue of gas warfare is emotional and political. In this respect it is similar to many issues facing our government today; communism and race relations are examples. Government officials have led the way with free and open discussions on these controversial subjects and should do the same with gas warfare. This leadership is essential, as Major General W.M. Creasy warned a House Science Committee in 1959:

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[11]"Public Understanding--The Ultimate Weapon?" The General Electric Defense Quarterly, Vol. 3, Oct.-Dec. 1960, p. 33.

[12]William Albig, Modern Public Opinion, p. 12.

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> I do not believe the American people are going to read any information on a subject when the American government says this is too horrible to use and we are not going to use it.[13]

The first step in a public information program is to go after the roots of public hostility towards gas warfare: World War I propaganda. The effects of the Allied propaganda did not evaporate with the gas clouds of World War I "for that half-century-old vision of the blue-faced men at Ypres choking to death, has left an indelible impression upon the mind of the world."[14] As late as 1953 the horrors of the first gas attack were brought out in the memoirs of a war correspondent who served with the Red Cross at Ypres:

> This horror was too monstrous to believe at first... the savagery of it, of the sight of men choking to death with yellow froth, lying on the floor and out in the fields, made me rage with an anger which no later cruelty of man...ever quite rekindled; for then we still thought all men were human.[15]

The tragedy of the first gas attack should be admitted in any program of public information: the soldiers were helpless; those who did not panic and run suffered a slow and painful death. On the other hand, it should be pointed out that protection against chlorine was simple and was achieved before the second gas attack took place two days later. Ypres was an isolated incident.

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[13] Quoted in US Congress, House, Committee on Science and Astronautics, Chemical, Biological and Radiological Warfare Agents, p. 22.

[14] Hanson W. Baldwin, "After Fifty Years the Cry of Ypres Still Echoes--'GAS!'," New York Times Magazine, 18 Apr. 1965, p. 50.

[15] Geoffrey W. Young, The Grace of Forgetting, p. 233.

The best counter to propaganda is to tell the truth. In getting the facts to the public it is important to differentiate between information which can and cannot be made available to the public. They should know in general what is going on, but the details must remain classified to protect national security. It is important also to differentiate between information which should and should not be made available to the public. Articles on gas warfare should pass the test of one criterion before release by the Department of Defense: does it contribute to public understanding of gas warfare, or does it add to the misconceptions of mystery and indecency?

The free and open discussion on nuclear warfare has resulted in the willingness of the responsible American to accept the nuclear weapon as an unpleasant fact, essential to his country's safety. The current secrecy surrounding gas warfare can create a lack of confidence in the capabilities of gas. Captain Liddell Hart told of British tanks developed during World War II that were fitted with special searchlights for blinding the enemy as well as for night firing. This invention was "kept so secret that the commanders in the field regarded them distrustfully and thus repeatedly hesitated to employ such unfamiliar instruments."[19]

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[19]B.H. Liddell Hart, Deterrent of Defense, pp. 86-87.

FINAL REPORT

11 March 1963

Recovery and Decontamination Measures after Biological and Chemical Attack

This report has been reviewed in the Office of Civil Defense and approved for publication. Approval does not signify that the contents necessarily reflect the views and policies of the Office of Civil Defense.

Contract OCD-OS-62-183

Prepared for
Office of Civil Defense
Department of Defense

by

Science Communication, Inc.
1079 Wisconsin Avenue, N.W.
Washington 7, D. C.

To plan for countermeasures against any weapons one must understand the problem—the nature, the potentials, and the limitations. This research project and the resultant final report were intended to bring together current information most applicable to civil defense. It was particularly intended for those who are responsible for planning preparatory, reclamation and countermeasures effort to minimize the damage from a BW/CW attack.

William J. Lacy
Project Coordinator
Postattack Research

Decontaminants

An important class of decontaminants comprises the common substances or natural influences such as time, air, earth, water, and fire.

Natural Effects

Biological agents are living organisms and tend to die off with time unless they are in a favorable environment with moisture, food, warmth, and other factors necessary for their survival. In addition, most biological organisms are very sensitive to the conditions of temperature and humidity -- and, particularly to the ultra-violet portion of sunlight. Adverse exposure to the elements -- air, sunlight, high temperature, low humidity -- is effective, in fact, against all biological agents except the spore forms of bacterial organisms.

It is generally assumed that in the vegetative form bacteria (as contrasted to the spore form) can persist for less than two hours during daytime and about eighteen hours at night. Since these short-lived bacteria are the most probable agents, outdoor decontamination is usually not called for unless the agent has been identified, either by laboratory tests or by the character of the disease, as one which forms spores or is otherwise known to be persistent.

The persistent, low-volatile, agents such as the liquid nerve agents (V-agents) and the blister gases present the principal chemical decontamination problem. Even these evaporate in time. The speed of evaporation and dissipation is enhanced by higher temperatures and wind. Thus, if it is possible to avoid the area or the use of contaminated objects for a reasonable length of time, decontamination may be unnecessary. Such periods might run from hours to a few days, depending on the degree of contamination and weather conditions. In cold weather the agents will persist for longer periods.

Water

Next to weathering, the most important natural decontaminant is water, used either to remove the agent, with or without soap or detergents to assist, or by boiling. One caution -- water used to wash away contamination becomes contaminated and must be disposed of accordingly. Boiling destroys most chemical agents and all biological agents. When it is feasible, boiling is one of the most generally desirable methods -- particularly for household use by individuals.

Earth and fire, the other natural decontaminants, would have relatively little application in civil defense BW/CW decontamination operations. Earth may be used to cover contamination temporarily to keep it out of contact with people while natural processes either dissipate or destroy the agent. This involves substantial effort with bulldozers and earth-moving equipment and usually is neither practical or necessary.

Chemical Decontaminants

These are preferred when they are available. Chemical decontaminants fall in two classes -- those which destroy or neutralize the agents, and those which simply assist in their removal.

The principal decontaminants which destroy or neutralize are:

- Chlorine-containing materials, such as calcium hypochlorite (HTH) and sodium hypochlorite solutions. Many household disinfectants available under various brand names -- Clorox, Purex, etc. -- are sodium hypochlorite solutions.
- Alkalies, such as caustic soda (lye) and sodium carbonate (washing soda, or soda ash).

The chlorine-containing materials, in proper concentrations, are effective against both biological and chemical agents. As solutions they are used to decontaminate surfaces, as in washing off sealed food containers; for decontaminating cotton fabrics by soaking or addition during the washing process; and for sterilizing water. Hypochlorite solutions have the disadvantage of corroding metals and so must be rinsed off thoroughly.

The hypochlorites -- calcium and sodium -- are the preferred decontaminants for blister gases and liquid nerve agents. For most such applications they are used as solutions but for vertical surfaces or porous surfaces a "whitewash" of calcium hypochlorite (HTH), hydrated lime, and water (called a "slurry") is more effective

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FM 3-10

DEPARTMENT OF THE ARMY FIELD MANUAL

CHEMICAL AND BIOLOGICAL WEAPONS EMPLOYMENT

HEADQUARTERS, DEPARTMENT OF THE ARMY
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FIELD MANUAL No. 3-10

HEADQUARTERS,
DEPARTMENT OF THE ARMY
WASHINGTON 25, D.C., *20 February 1962*

CHEMICAL AND BIOLOGICAL WEAPONS EMPLOYMENT

CHAPTER 1

INTRODUCTION

1. Purpose

This manual provides guidance to commanders and staff officers in the employment of chemical and biological weapons. It contains a brief summary of background knowledge of chemical and biological agents and munitions and the procedures to be followed in planning their employment.

2. Scope

a. General. Considerations are limited to chemical and biological agents and delivery systems that are type-classified or expected to be type-classified during the period ending December 1965. The chemical agents are nerve agent GB, nerve agent VX, and blister agent HD. The agent delivery means are artillery and mortar shells, rocket and missile warheads, aircraft bombs, and spray devices. FM 3–10A contains the classification and characteristics of biological agents and information on biological munitions and delivery systems. Troop safety considerations are presented. This manual is applicable to nuclear and nonnuclear warfare.

b. Chemical Agents. Chapters 3 through 8 contain a discussion of chemical agents and their characteristics; factors affecting the employment of chemical agents; chemical munitions and delivery systems and the concepts for their employment; and target analysis, fire planning, and logistical considerations. Methods of chemical target analysis presented are suitable for fire planning and casualty assessment at all echelons of command having chemical fire planning and assessment responsibilities.

c. Biological Agents. Chapters 9 through 13 contain a discussion of biological agents and their characteristics; factors affecting the employment of biological agents; biological munitions and delivery systems and the concepts of their employment; and target analysis, effects assessments, and logistical considerations. Only the antipersonnel effects of biological agents are considered. The methods of biological weapons target analysis presented are suitable for biological fire planning and casualty assessment. The unique character of biological munitions supply and field management is presented.

d. Reliability. The data and procedures presented in this manual have been extracted or derived from official studies and from research and development documents. The potential performance of materiel is based on field trial data with simulants and selected live agents and on theoretical calculations and assumptions developed from mathematical models. The procedures are therefore subject to change as may be required by future developments or refinements. It should be noted that the flow of a chemical or biological agent cloud over the terrain cannot be predicted with a high degree of precision. This is due principally to the inability to predict accurately the prevailing atmospheric conditions of the area under consideration with respect to the diffusion and dissipation of an agent cloud. Nevertheless, the methods and procedures presented here provide information with sufficient accuracy to be used with reasonable confidence.

e. User Comments. Users of this manual are encouraged to submit recommended changes or comments to improve the document. Comments should be keyed to the specific page, paragraph, and line of the text in which change is recommended. Reasons should be provided for each comment to insure understanding and complete evaluation. Comments should be forwarded direct to the Commandant, U.S. Army Chemical Corps School, Fort McClellan, Ala.

3. The Role of Chemical Agents in Military Operations

a. Chemical weapons increase the flexibility of the integrated weapons systems and place at the commander's disposal a highly effective means of conducting antipersonnel operations.

b. In the conduct of military operations involv-

ing chemical weapons, some factors that should be considered are—

(1) The chemical agents discussed herein do not destroy materiel. On the contrary, they allow the physical preservation of industrial complexes, cultural institutions, lines of communications, and other facilities and materiel that may be useful to friendly forces or that merit preservation for political or economic reasons.

(2) Chemical munitions do not produce physical obstacles to maneuver, since they cause minimal destruction, blowdown, rubble, and similar barriers. Agents that produce a persistent effect, however, will create a hazard to friendly troops.

(3) Chemical agents may be employed to produce a variety of effects ranging from harassment to lethality.

(4) Toxic chemical clouds penetrate fortifications and similar structures that are not airtight.

(5) Because of their area coverage effect, chemical agents, used in mass, are particularly effective in attacking targets whose location is not precisely known.

(6) Chemical munitions are particularly effective for producing casualties among dug-in personnel who are not provided with chemical protection.

(7) Chemical agents increase the flexibility of the entire spectrum of firepower available to the commander.

(8) Chemical agents may be used to follow up and exploit advantages gained by other means.

(9) Because the effectiveness of chemical agents on the target is influenced by the type and quantity of agent employed and by the method of dissemination, meteorological factors, conditions of the target, and protection and training of enemy troops, it is difficult to predict the results of employment accurately.

(10) Chemical agents may produce hazards to friendly forces because of residual contamination and cloud movement.

4. Chemical Agents

a. The following three type-classified chemical agents provide commanders flexibility in their employment of chemicals.

(1) Nerve agent GB is a rapid-acting lethal agent that is used primarily for respiratory effects against unprotected personnel and for surprise attack against personnel having masks available.

(2) Two agents are used in circumventing the protective mask.

(*a*) VX is a slow-acting lethal nerve agent when absorbed percutaneously. If inhaled as an aerosol or vapor, VX acts as rapidly as GB and is more toxic.

(*b*) HD is a slow-acting casualty agent with a limited lethal effect. It attacks the skin in liquid or vapor form and is also effective by inhalation.

b. The following figures describe GB and HD in more detail. Detailed information on VX is contained in FM 3–10A. More comprehensive data on chemical agents are in TM 3–215.

1. Primary use	Nonpersistent, rapid-acting lethal agent used primarily for respiratory effect.
2. Average time to incapacitation	15 minutes after exposure to an incapacitating dosage; for lethal dosages, death in 5 minutes after appearance of symptoms if untreated.
3. Duration of incapacitation	1 to 5 days for return to duty. (30 to 60 days for return to normal blood cholinesterase level.)
4. Signs and symptoms	Tightness of chest, pinpointing of eye pupils, dimness of vision, excessive sweating, drooling; followed by tension, giddiness, tremors, confusion, slurred speech, weakness, convulsions, and death.
5. Physiological effects	Nerve poison; slow detoxification by body (60 days); effects of successive small dosages considered cumulative for short periods of time (weeks).
6. Route of entry	Inhalation; percutaneous entry by liquid or high vapor concentration is unlikely in the field because of the high dosage required.
7. Protection	Mask against vapor; protective clothing against liquid agent.
8. Limitations	Mask offers adequate protection against vapor for trained and warned personnel.
9. Duration of hazard	The area in and around shell or bomb craters will be contaminated and will remain a hazard to unprotected personnel for periods ranging from 6 hours to several days.
10. Physical properties	Clear, colorless, odorless liquid; freezing point minus 56° C (−69° F.); boiling point 147° C (297° F.); evaporates at approximately the same rate as water.

Figure 1. Characteristics of nerve agent GB.

1. Primary use	To cause delayed casualties by liquid and vapor effect on the skin and eyes and by vapor effect through the respiratory system.
2. Average time to incapacitation	Eye effect 3 to 12 hours; skin effect 3 to 24 hours.
3. Duration of incapacitation	Eye effect 1 to 7 days; skin effect 1 to 4 weeks.
4. Signs and symptoms	Inflammation of eyes; redness of skin; blistering; ulceration.
5. Physiological effects	Produces blisters and destroys tissues.
6. Route of entry	Skin absorption of vapor or liquid and inhalation of vapor.
7. Protection	Mask, ointment, and protective clothing.
8. Limitations	Limited effectiveness in freezing weather; greater dosages are required for casualty production than are required with GB or VX.
9. Duration of hazard	36 hours to several days. See figure 2.1d.
10. Physical properties	Clear oily liquid with garliclike odor; moderately volatile; freezing point 14° C. (57° F.); boiling point 228° C. (442° F.).

Figure 2. Characteristics of blister agent HD.

Times given indicate approximate time after contamination that personnel may operate in the area

Task	Terrain	Protection (Based on expenditures between 240 and 1,200 pounds of HD per hectare)			
		With protective clothing and wearing masks		Without protective clothing [1]	
		Temperature		Temperature	
		16°–27° C. (60°–80° F.)	Above 27° C. (80° F.)	16°–27° C. (60°–80° F.)	Above 27° C. (80° F.)
		Hours	*Hours*	*Days*	*Days*
TRAVERSAL [2] (Walking across area up to 2 hr)	Bare soil, sand, or short grass	0	0	[3] 1½	[3] 1½
	Low vegetation	4	2	[3] 1½	[3] 1½
	High vegetation, including jungle and heavy woods.	12	6	[3] 4	[3] 2
ADVANCE UNDER FIRE (Contact with ground, 1 hr; total time in area, 2 hr).	Bare soil or low vegetation	24	8	[3] 3	[3] 2
	High vegetation, including jungle and heavy woods.	48	24	[3] 6	[3] 4
OCCUPATION (Without hitting ground, 24 hr)	Bare soil or low vegetation	1	1	[4] 4	[4] 3
	High vegetation, including jungle and heavy woods.	1	1	[4] 4	[4] 3
OCCUPATION (Involving advance under fire, 24 hr).	Bare soil or low vegetation	24	8	[4] 4	[4] 3
	High vegetation, including jungle and heavy woods.	48	24	[4] 6	[4] 4

[1] For men walking in a contaminated area for 2 hours without protective clothing, the limiting factor is the vapor.
[2] For men with protective clothing, when traversal is made in daylight and areas of heavy contamination can be avoided or decontaminated, the times can be reduced to about one-half of those indicated above.
[3] Wearing masks.
[4] Not wearing masks.

Figure 3. Duration of HD hazard in target area.

Additional micrometeorological characteristics of the zone of operations are obtained through the following methods:

(1) Aerial reconnaissance and observations.
(2) Ground reconnaissance and observations.
(3) Observations of fog, smoke, and dust in the zone of operations.
(4) Field expedient methods for obtaining micrometeorological data in the vicinity of the target area.
(5) Statistical studies of weather in the theater of operations.

b. A suggested format for transmission and recording of basic weather data is illustrated in appendix II. It is emphasized that in chemical target analysis, the weather predictions are required for a period of time after the attack as well as for the time of the chemical attack.

c. Normally, Air Weather Service detachments are stationed at field army, corps and division headquarters. From these sources a target analyst may obtain weather data and weather briefings, or he may request detailed operational and planning forecasts and climatological information.

10. Temperature

The rate of evaporation of chemical agents increases as the temperature rises. High temperatures cause personnel to perspire more freely, thus opening the pores of the skin and accelerating penetration of the skin by the agent. At low temperatures, extra layers of clothing increase the barrier to the skin.

11. Temperature Gradient

The temperature gradient is an expression of the difference in air temperature at two levels. In the United States Army, it is determined by subtracting the air temperature (Fahrenheit) measured one-half meter above the ground from the air temperature 2 meters above the ground. The three characteristic conditions that are associated with the temperature gradient follow:

a. Lapse. A decrease in air temperature with an increase in height is known as a *lapse* condition. Such a condition normally exists on a clear or partially clear day and is characterized by heat turbulence. It is the least desirable condition for chemical operations because of rapid dissipation of agent clouds.

b. Inversion. An increase in air temperature with an increase in height is known as an *inversion* condition. This condition exhibits a minimum of turbulence and usually exists on a clear or partially clear night or early morning. This is the most desirable condition for chemical operations since the agent cloud tends to remain in the cooler layers of the air near the ground.

c. Neutral. A condition intermediate between lapse and inversion is known as a *neutral* condition. Such a condition prevails when there are small differences in temperature at the two levels and usually exists on heavily overcast days or nights, and shortly after sunrise and near sunset.

12. Wind

The wind is also an important weather element affecting the field behavior of chemical clouds. Of the wind characteristics, velocity and direction have greatest influence. Both characteristics are influenced by terrain and temperature gradient.

a. Velocity. Air moving over an irregular surface sets up eddies, or mechanical turbulence. This turbulence is similar to heat turbulence in that it acts to dissipate a chemical cloud. High wind velocities also cause the agent cloud to pass rapidly over the target area, thus reducing the exposure time. Some air movement is desired to blend the individual clouds of agent formed by each shell burst into a uniform cloud covering the target. Ideal wind velocities for chemical operations are 3 to 9 knots (approximately 6 to 16 kilometers per hour). Wind velocities in excess of 16 knots (approximately 30 kilometers per hour) are not suitable for nonpersistent effects.

b. Direction. Wind directs the travel of a chemical cloud. This fact must be considered in the release of an agent for coverage of a particular target and in the determination of the downwind hazard to friendly troops. The wind direction is the direction from which the wind blows and is expressed in terms of azimuth in mils or degrees.

13. Precipitation

Precipitation has an adverse effect on the behavior of chemical agents, since rain will wash away the liquid agent contamination and snow will cover it. Precipitation also washes agent vapors or aerosol clouds from the air and destroys some agents by hydrolysis.

	1	2	3	4	5			
					Employment data			
					(a)		(b)	(c)
Line	Munition	Agent	Delivery system	User	Range (1) (Meters) (2)		Error	Fuze (Capability)
					Maximum	Minimum		
1	Shell, M2A1	HD	4.2-inch Mortar	US ARMY USMC	3, 930	180	←Obtain from delivery unit or appropriate firing tables→	M8PD
2	Shell, M360	GB	105-mm Howitzer, M2A1, M2A2, M4, M4A2, M52.	US ARMY USMC	11, 140	862		M508PD
3	Shell, M60	HD	105-mm Howitzer, M2A1, M2A2, M4, M4A2, M52.	US ARMY USMC	11, 140			M51A5PD
4	Shell, M121	GB	155-mm Howitzer, M1, M1A1, M44.	US ARMY USMC	14, 950			M508PD
5	Shell, M110	HD	155-mm Howitzer, M1, M1A1, M44.	US ARMY USMC	14, 950			M51A5PD
6	Shell, T__(M121)	VX	155-mm Howitzer, M1, M1A1, M44.	US ARMY USMC	14, 950			T76E6VT [1]
7	Shell, M122	GB	155-mm Gun, M2, M53	USMC	23, 500			M508PD
8	Shell, M104	HD	155-mm Gun, M2, M53	USMC				M51A5PD
9	Shell, Gas, 175-mm	GB	M107 Gun (SP)	US ARMY	31, 500	180		
10	Shell, Gas, 175-mm	VX	M107 Gun (SP)	US ARMY	31, 500	180		VT-M514A1
11	Shell, T174	GB	8-inch Howitzer, M2, M2A1, M55.	US ARMY USMC	16, 930			M51A5PD
12	Shell, T174	VX	8-inch Howitzer, M2, M2A1, M55.	US ARMY USMC.	16,930			T2061VT
13	Rocket, M55, 115-mm (BOLT)	GB	Launcher, M91	US ARMY USMC.	10,970	2,740		M417PD
14	Rocket, M55, 115-mm (BOLT)	VX	Launcher, M91	US ARMY USMC.	10,970	2,740		T2061VT
15	Warhead, M79, 762-mm (HONEST JOHN).	GB	Rocket, M31A1C Launcher, M386.	US ARMY USMC.	24,960	8,500		T2075 Mech Time
16	Warhead, E19R2, 762-mm (HONEST JOHN).	GB	Rocket, XM50 Launcher, M386.	US ARMY USMC.	33,830	8,500		T2075 Mech Time
17	Warhead, E19R2, 762-mm (HONEST JOHN).	VX	Rocket, XM50 Launcher, M386.	US ARMY USMC.	33,830	8,500		T2075 Mech Time
18	Warhead, E20, 318-mm (LITTLE JOHN).	GB	Rocket, XM51 Launcher, XM80.	US ARMY USMC.	18,290	3,200 [1]		T2075 Mech Time
19	Warhead, E21, (SERGEANT)	GB	Rocket, Launcher	US ARMY	139 km	50 km	304m	Preset Radar
20	Warhead, E21, (SERGEANT)	VX	Rocket, Launcher	US ARMY	139 km	50 km	304m	Preset Radar
21	Bomb, M34A1, 1000-lb, Cluster	GB	Fighter, Bomber	USAF	Range of Aircraft.		←Obtain from delivery unit→	M152E3 Mech Time
22	Bomb, MC-1, 750-lb	GB	Fighter, Bomber	USAF	Range of Aircraft.			M905BD
23	Projectile, 5"/38, MK53, MOD O	GB	5-inch Gun	US NAVY	16,450			MK29MOD3PD
24	Projectile, 5"/54, MK54, MOD O	GB	5-inch Gun	US NAVY	19,200			MK30MOD3PD
25	Warhead, Rocket, 5" MK40, MOD O.	GB	Launcher, MK 105 Rocket, M40, MOD O.	US NAVY	4,200			MK30MOD3PD
26	Warhead, Rocket, 5", MK40, MOD O.	HD	Launcher, MK 105 Rocket, M40, MOD O.	US NAVY	4,200			MK30MOD3PD
27	Bomb, MK94, MOD O	GB	Fighter, Bomber	US NAVY	Range of Aircraft.			AN-M103A1ND M195 BD (IMPACT).
28	Bomb, M70A1	HD	Fighter, Bomber	US NAVY	Range of Aircraft.			AN-M158ND (IMPACT).
29	Mine, Land, Chemical, M23	VX	N/A	US ARMY	N/A	N/A	N/A	
30	Mine, Land, Chemical, One-Gallon.	HD	N/A	US ARMY	N/A	N/A	N/A	

See notes at end of figure.

Figure 5. Chemical munitions and delivery systems.

5 Employment data—Continued						6 Functioning and physical characteristics of CML munitions				
(d) Time for delivery		(e)	(f)	(g)	(h)	(a)	(b)	(c)	(d)	(e)
(1) Preplanned	(2) Target of opportunity	Organization	Rate of fire per weapon	Height of burst	Diameter (meters) of impact area (single rd) [2]	Weight of munition (kg)	Weight of agent (kg)	Effective weight of agent (kg) [3]	Functioning efficiency of munition (percent)	Agent dissemination efficiency
----------	----------	6 Mort/Plt 8 Mort/Btry	30 Rds/2 min 105 Rds/15 min	GND	16	10.8	2.72	----------	99	
----------	1–3 min	6 How/Btry	6 Rds/½ min 18 Rds/4 min	GND	27	16.1	.739	----------	99	
----------	1–3 min	6 How/Btry	6 Rds/½ min 18 Rds/4 min	GND	11	15.2	1.22	----------	99	
----------	1–5 min	6 How/Btry	3 Rds/½ min 12 Rds/4 min	GND	49	45.9	2.95	----------	99	
----------	1–5 min	6 How/Btry	3 Rds/½ min 12 Rds/4 min	GND	20	42.0	4.4	----------	99	
----------	1–5 min	6 How/Btry	3 Rds/½ min 12 Rds/4 min	20m [1]	----------	45.9	2.95	----------	99	
----------	1–5 min	4 Gun/Btry	2 Rds/½ min 8 Rds/4 min	GND	49	45.9	2.95	----------	99	
----------	1–5 min	4 Gun/Btry	2 Rds/½ min 8 Rds/4 min	GND	22	43.0	5.31	----------	----------	
		4 Gun/Btry	----------	GND	----------	66.8	6.68	----------	----------	
----------	----------	4 Gun/Btry	----------	GND	----------	66.8	6.04	----------	----------	
----------	½–6 hr	4 How/Btry	6 Rds/4 min 10 Rds/10 min	GND	76	97.0	7.12	----------	99	
----------	½–6 hr	4 How/Btry	6 Rds/4 min 10 Rds/10 min.	20m [1]	----------	97.0	7.12	----------	99	
----------	30 min	36 Lchr/Bn	45 Rkt/Lchr/15 sec.	GND	46	26.4	4.80	----------	99	
----------	30 min	36 Lchr/Bn	45 Rkt/Lchr/15 sec.	20m [1]	----------	26.2	4.54	----------	99	
----------	15 min	2 Lchr/Bn	2/Hr	Variable	Variable	737	177.5	104.8	95	62 percent.
----------	15 min	2 Lchr/Btry	2/Hr	Variable	Variable	568	210	171	95	86 percent.
----------	15 min	2 Lchr/Btry	2/Hr	Variable	Variable	568	210			
----------	15 min	4 Lchr/Btry	2/Hr	Variable	Variable	119	30			
15 min	120 min	4 Lchr/Bn	2/Day	Intervals of 1,524m.	Variable	744	190			
15 min	120 min	4 Lchr/Bn	2/Day	Intervals of 1,524m.	Variable	744	190			
----------	15 min +flight time.	----------	2–6/Ftr 4–18/Bmbr.	Variable	170	513	89.6	----------	90	
----------	15 min +flight time.	----------	2–6/Ftr 4–27/Bmbr.	GND	127	322	99.9			
----------	----------	----------	----------	GND	35	25.1	1.47			
----------	----------	----------	----------	GND	40	29.1	2.02			
----------	----------	----------	48 Rkt/Lchr/ 1 min	GND	49	22.9	2.18			
----------	----------	----------	48 Rkt/Lchr/ 1 min	GND	----------	----------	----------			
----------	----------	----------	----------	GND	90	222	49.8			
----------	----------	----------	----------	GND	29	58.0	272			
----------	----------	----------	----------	----------	----------	10.50	5.23			
----------	----------	----------	----------	----------	----------	5.45	4.50			

[1] Estimated.
[2] Instantaneous agent area coverage 30 seconds after detonation.
[3] Values are the product of values given in columns 6(*b*), 6(*d*), and 6(*e*). Since values for 6(*e*) are not available, values for 6 (*c*)cannot be computed at this time.

Figure 5.—Continued

Agent—GB.
Wind speed—5 knots (approx 9 km/hr).
Temperature gradient—inversion.
Temperature—60° F. (15.5° C.).
Terrain—open, level, scattered vegetation.
Precipitation—none.
Time limitations on the delivery of agent on target—4 minutes or less.
Casualty level desired—20 percent.

Find: Whether or not the mission can be fired with a 105-mm howitzer battery.

Solution:

(*a*) Using figure 11, convert 20 percent casualties among protected personnel to the corresponding casualty level among unprotected personnel. This is 80 percent.

(*b*) Using the "GB (over 30-sec attack)" column of figure 12, determine the total effects components to be 3.21 as follows:

Inversion	1. 09
Wind speed, 9 km/hr	1. 00
Temperature, 60° F. (15.5° C.)	. 12
Open terrain	. 30
No precipitation	. 70
	3. 21

(*c*) Using figure 13, place a hairline between 80 percent on the percent casualties scale and 12 hectares on the target area scale. On the point of intersection on the reference line, pivot the hairline until it intersects 3.21 on the effects components scale. On the munitions expenditure scale, read 12 as the number of 155-mm equivalents required.

(*d*) To find the number of 105-mm rounds required to fire the mission, multiply 12 by a factor of four (obtain this factor from figure 8); the product is 48 rounds.

(*e*) From figure 9, it is evident that one battery of six howitzers can easily fire the mission if no shift of fires is required. Since the target is twice as large as the dispersion pattern of a 105-mm battery (par. 31*c*(3)(*c*) and 41*d*), a shift of fires should be made. Figure 9 gives a time of 30 seconds for shifting of fires. On this basis the battery could fire twenty-four rounds on half the target in a little less than 30 seconds, take 30 seconds to shift fires, and have ample time to deliver the remaining twenty-four rounds on the other half of the target. The firing should be completed in less than 2 minutes.

Munition	Munition expressed in terms of 155-mm chemical equivalents		
	GB	VX	HD
155-mm Shell	1	1	1
105-mm Shell	0. 25	--------	0. 28
8-inch Shell	2. 40	2. 17	--------
4.2-inch Mortar Shell	--------	--------	. 62
175-mm Shell	2. 1	2. 1	--------
M55 Rocket	1. 6	1. 6	--------
M79 Warhead—HONEST JOHN	60	--------	--------
E19R2 Warhead—HONEST JOHN	71	71	--------
LITTLE JOHN	10	10	--------
SERGEANT	65	65	--------
M34A1 1000-lb Cluster	30	--------	--------
MC1 750-lb Bomb	35	--------	--------
5″/38 Gas Projectile (Navy)	. 50	--------	--------
5″/54 Gas Projectile (Navy)	. 68	--------	--------
5″ Gas Rocket (Navy)	. 74	--------	--------
500-lb Gas Bomb	17	--------	--------
115-lb Gas Bomb (Navy)	--------	--------	6. 2

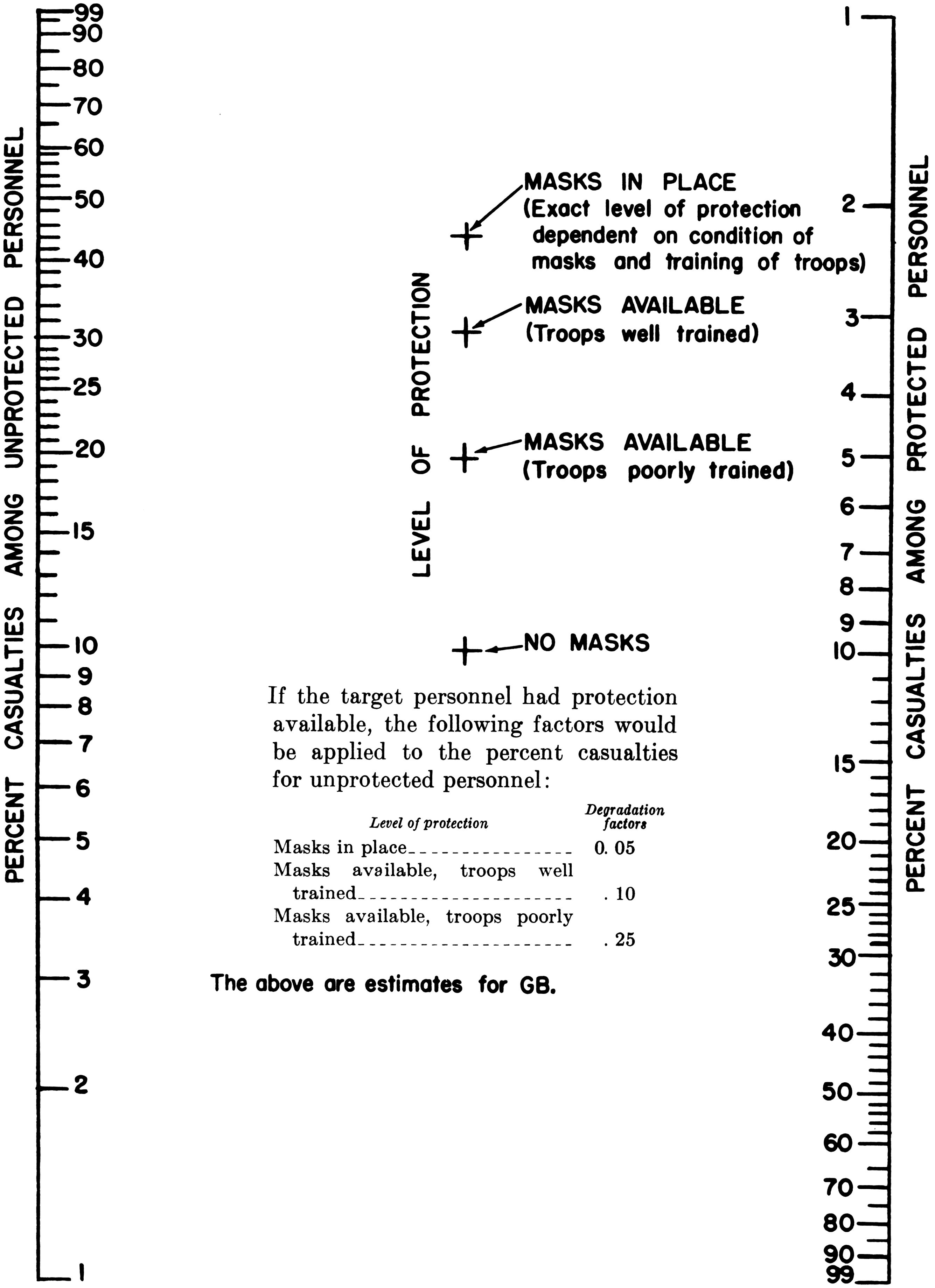
Figure 7. Munitions expressed in terms of 155-mm chemical equivalents. (The figures given are an estimate of the number of 155-mm howitzer rounds required to give the same effect as one round of the specified munition. Dissemination efficiency has not been considered.)

Munition	Conversion factor		
	GB	VX	HD
155-mm Shell	1	1	1
105-mm Shell	4	--------	3. 6
8-inch Shell	0. 41	0. 45	--------
4.2-inch Mortar Shell	--------	--------	1. 61
175-mm Shell	. 48	. 48	--------
M55 Rocket	. 61	. 61	--------
M79 Warhead—HONEST JOHN	. 017	--------	--------
E19R2 Warhead—HONEST JOHN	. 014	. 014	--------
LITTLE JOHN	. 098	. 098	--------
SERGEANT	. 016	. 016	--------
M34A1 1000-lb Cluster	. 033	--------	--------
MC1 750-lb Bomb	. 029	--------	--------
5″/38 Gas Projectile (Navy)	2. 00	--------	--------
5″/54 Gas Projectile (Navy)	1. 46	--------	--------
5″ Gas Rocket (Navy)	1. 35	--------	--------
500-lb Gas Bomb	. 059	--------	--------
115-lb Gas Bomb (Navy)	--------	--------	. 164

Figure 8. Conversion factors for converting 155-mm munitions to other munitions.

Weapon	Maximum rate (rounds)	Rates of fire for chemical fire missions without shifting or relaying of the piece (rounds)					Estimated time to shift fires
	30 sec	1 min	2 min	4 min	10 min	15 min	
105-mm Howitzer	6	10	14	18	40	60	30 sec
155-mm Howitzer	3	5	7	12	30	40	30 sec
155-mm Gun	2	4	6	8	12	18	60 sec
8-inch Howitzer	1	2	3	6	10	15	60 sec
4.2-inch Mortar	10	16	30 (max)	50	80	105	30 sec
M91 Launcher (M55 Rocket)	45 (15 sec)	Launcher must relocate after firing each ripple.					

Figure 9. Approximate rates of fire for division cannon artillery, mortars, and multiple rockets firing chemical rounds. (Rates of fire for other weapons are given in figure 5.)



If the target personnel had protection available, the following factors would be applied to the percent casualties for unprotected personnel:

Level of protection	*Degradation factors*
Masks in place	0. 05
Masks available, troops well trained	. 10
Masks available, troops poorly trained	. 25

The above are estimates for GB.

Figure 11. Nomogram for conversion of percent GB casualties for protection of personnel in the target area.

Meteorological and terrain conditions	Effects components			
	GB [2] (surprise attack)	GB (over 30-sec attack)	VX	HD
1. *Temperature Gradient*				
Inversion	0.67	1.09	1.89	0.69
Neutral	.57	.69	1.89	.54
Lapse	.30	.09	1.89	.32
2. *Wind Speed (km/hr)*				
0 to 5	.20	1.30	0	.87
6 to 10	.50	1.00	0	.70
11 to 16	.70	.70	0	.60
17 to 26	.55	.30	0	.48
27 to 52	.30	0	0	0
3. *Temperature (° F.)*				
a. 0 to 39 (−18° to 4° C.)	0	0	0	----------
40 to 79 (5° to 26° C.)	.12	.12	0	----------
80 and up (27° C. and up)	.23	.23	0	----------
b. 30 to 49 (−1° to 9° C.)	----------	----------	0	0
50 to 69 (10° to 21° C.)	----------	----------	0	.70
70 and up (22° C. and up)	----------	----------	0	1.00
4. *Terrain*				
Open, level, scattered vegetation	.30	.30	0	.30
Rugged, mountainous	0	[1] 0	[1] 0	[1] 0
5. *Precipitation*				
None	.70	.70	.70	0
Moderate rain	0	[1] 0	[1] 0	[1] 0

[1] Estimated.
[2] Tentative figures not yet verified.

Figure 12. Effects components.

Note: paragraph 105 on page 82 states that the "safe entry times" after bio attacks are:

NU (Venezuelan equine encephalitis virus),
AB (bovine brucellosis), and
UL (tularemia): 2 hrs sun or 8 hrs cloudy
OU (Q fever): 2 hrs sun or 18 hrs cloudy

Cloudy conditions also apply to nighttime

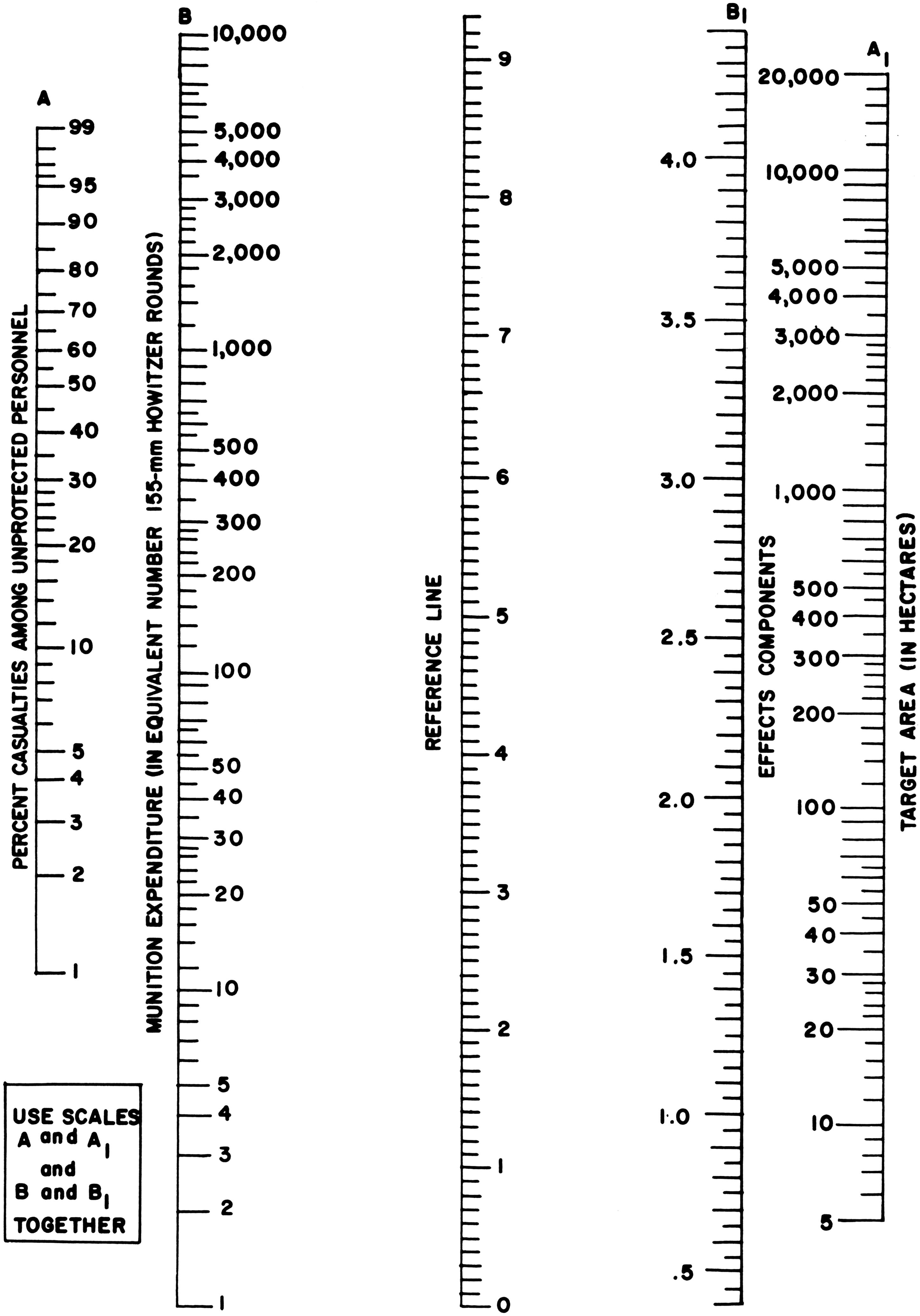


Figure 13. Target area, casualty level, munitions requirement nomogram.

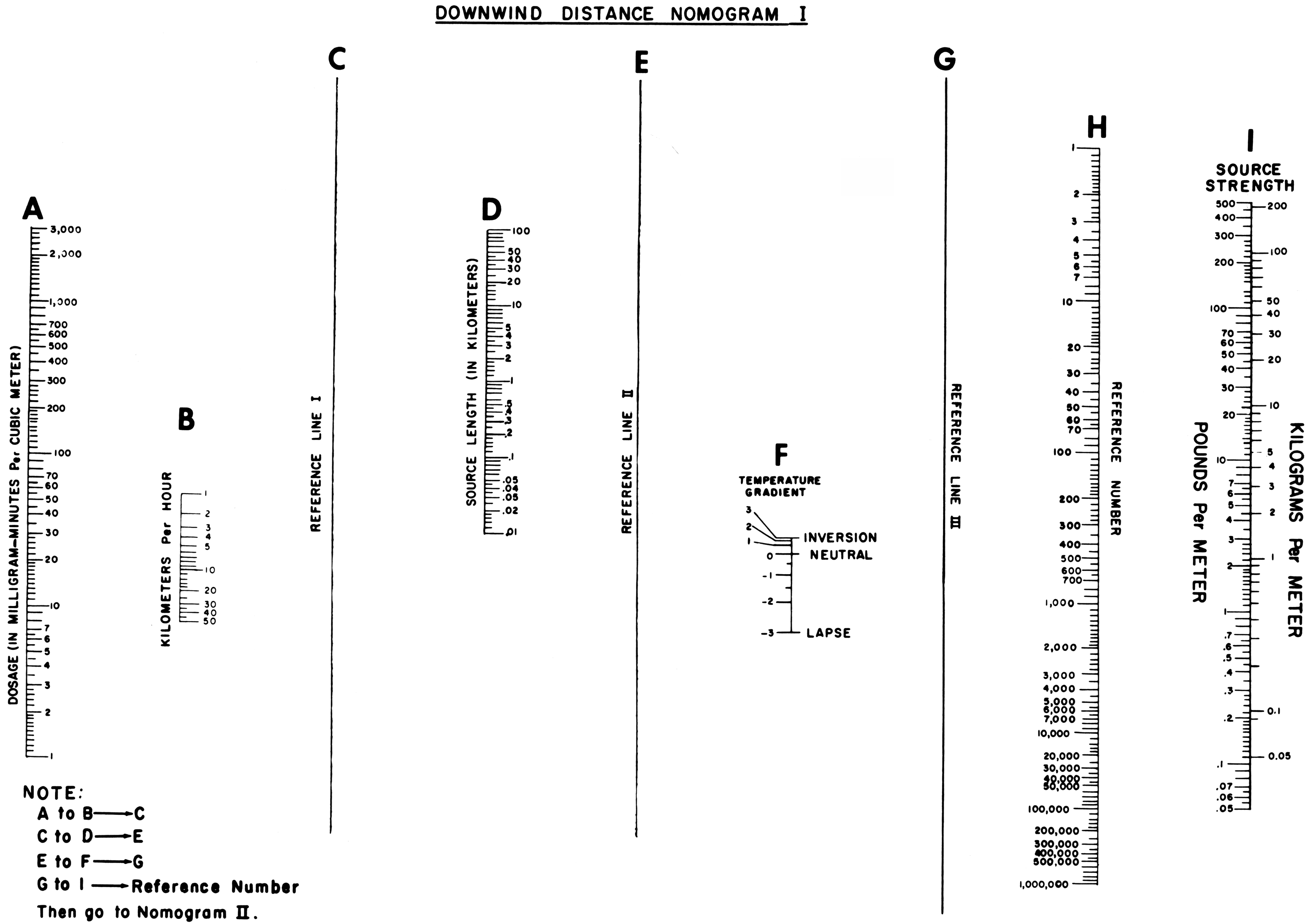


Figure 14. Downwind distance nomogram I.

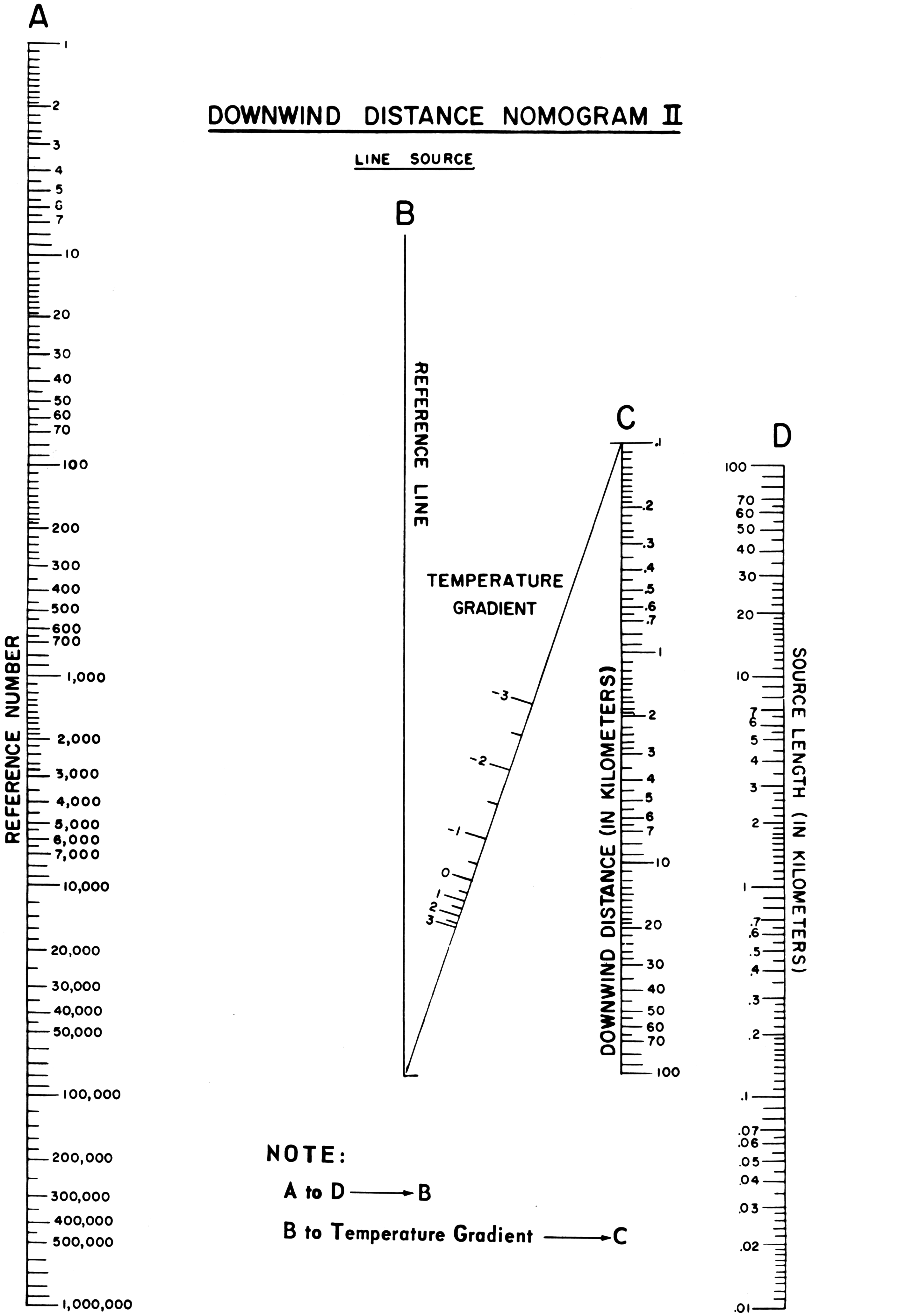


Figure 15. Downwind distance nomogram II.

USACGSC **RB 3-1**

REFERENCE BOOK

CHEMICAL AND BIOLOGICAL WEAPON EMPLOYMENT

U.S. ARMY COMMAND AND GENERAL STAFF COLLEGE
Fort Leavenworth, Kansas

1 May 1968

This reference book supersedes RB 3-1, 1 May 1967

CHAPTER 2
TOXIC CHEMICAL AGENTS

1. Characteristics and Effects

a. General. The following antipersonnel chemical agents are used for College instruction in chemical weapon employment: nerve agents GB and VX; blister agent HD (mustard); and incapacitating agent BZ. Actual or assumed characteristics of these agents are described in the following paragraphs for instructional purposes only and are summarized in figure 1.

b. Nerve Agent GB. GB is a quick acting, nonpersistent lethal agent that produces casualties primarily by inhalation.

(1) Inhalation effects. Inhaled GB vapor can produce casualties within minutes. As an example, 50 percent of a group of unprotected troops engaged in mild activity, breathing at the rate of about 15 liters per minute, and exposed to 70 milligrams of GB per cubic meter of air for 1 minute will probably die if they do not receive medical treatment in time. This is the median lethal dosage (50) and is expressed as 70 mg-min/m^3. For troops engaged in activities that increase their breathing rate, the median lethal dosage can be as low as 20 mg-min/m^3. The median incapacitating dosage of GB vapor by inhalation is about 35 mg-min/m^3 for troops engaged in mild activity. Incapacitating effects consist of nausea, vomiting, diarrhea, and difficulty with vision, followed by muscular twitching, convulsions, and partial paralysis. Dosages of GB less than the median incapacitating dosage cause general lowering of efficiency, slower reactions, mental confusion, irritability, severe headache, lack of coordination, and dimness of vision due to pinpointing of the eye pupils.

(2) Percutaneous effects. Percutaneous effects refer to those effects produced by the absorption of the agent through the skin. GB vapor absorbed through the skin can produce incapacitating effects. Sufficient GB liquid absorbed through the skin can produce incapacitation or death. The effectiveness of the liquid or vapor depends on the amount absorbed by the body. Absorption varies with the original amount of agent contamination, the skin area exposed and the exposure time, the amount and kind of clothing worn, and the rapidity in removing the contamination and/or contaminated clothing and in decontaminating affected areas of the skin.

(3) Major considerations in the employment of nerve agent GB. The employment of GB is based primarily on achieving casualties by inhalation of the nonpersistent vapor (or aerosol) of the agent. Major considerations in the employment of this agent are:

(a) Time to incapacitate. The onset of incapacitation resulting from inhalation of casualty-producing doses is rapid, the average time being approximately 3 minutes. To allow for the time required for the agent cloud to reach the individual, 10 minutes is used as the mean time to achieve incapacitation. Nonlethal casualties from GB will be incapacitated for 1 to 5 days.

(b) Persistency. Persistency is defined as the length of time an agent remains effective in the target area after dissemination. Nerve agent GB is considered nonpersistent. GB clouds capable of producing significant casualties will dissipate within minutes after dissemination. Some liquid GB will remain in chemical shell or bomb craters for periods of time varying from hours to days, depending on the weather conditions and type of munition. Because of this continuing but not readily discernible threat, GB can also be highly effective in harassing roles by causing exposure to low concentrations of the vapor. Rounds fired sporadically may compel the enemy to wear protective masks and clothing for prolonged periods, thereby impairing his effectiveness as a result of fatigue, heat stress, discomfort, and decrease in perception.

(c) Level of protection. The weapon system requirements for positive neutralization of masked personnel by GB are too great to be supported except for important point or small area targets. A major factor affecting casualties resulting from GB attacks of personnel equipped with masks but unmasked at the time of attack is the time required for enemy troops to mask after first detecting a chemical attack. Therefore, surprise dosage attack is used to establish a dosage sufficient to produce the desired casualties before troops can mask. Casualty levels for surprise dosage attack that are tabulated in the weapon system effects tables (app A) are based on an assumed enemy masking time of 30 seconds. (Refer to FM 3-10 series manuals for operational data for masking times less than 30 seconds.) A total dosage attack is used to build up the dosage over an extended period of time and is normally employed against troops who have no protective masks available. Dosages built up before troops can mask inside foxholes, bunkers, tanks, buildings, and similar structures will generally be less than dosages attained during the same period of time in the open, thereby reducing the effects on occupants from surprise dosage attacks. Total dosage effects are essentially the same inside or outside.

c. Nerve Agent VX. VX is a slow-acting, lethal, persistent agent that produces casualties primarily by absorption of droplets through the skin.

(1) Effects. VX acts on the nerve systems of man; interferes with breathing; and causes convulsions, paralysis, and death.

(2) Major considerations in the employment of nerve agent VX.

(a) General. Agent VX disseminated in droplet (liquid) form provides maximum duration of effectiveness as a lethal casualty threat. VX will remain effective in the target area for several days to a week depending on weather conditions. Because of its low volatility, there is no significant vapor hazard downwind of a contaminated area. Except when disseminated by aircraft spray tanks, meteorological conditions have little effect on the employment of VX, although strong winds may influence the distribution of the agent and heavy rainfall may wash it away or dissipate it.

(b) Employment to cause casualties. Agent VX is appropriate for direct attack of area targets containing masked personnel in the open or in foxholes without overhead protection, for causing severe harassment by the continuing casualty threat of agent droplets on the ground or on equipment, and for creating obstacles to traversing or occupying areas. Casualties produced by agent VX are delayed, occurring at times greater than 1 hour after exposure. Although this agent can be used relatively close to friendly forces, it should not be used on positions that are likely to be occupied by friendly forces within a few days. Because of this continuing hazard, areas in which agent VX has been used should be recorded in a manner similar to minefields or fallout areas so that necessary precautions can be taken.

d. Blister Agent HD. HD, sometimes referred to as mustard, is a persistent slow-acting agent that produces casualties through both its vapor and liquid effects.

(1) Vapor effects.

(a) The initial disabling effect of HD vapor on unmasked troops will be injuries to the eyes. Temporary blindness can be caused by vapor dosages that are insufficient to produce respiratory damage or skin burns. However, skin burns account for most injuries to masked troops. The vapor dosages and the time required to produce casualties (4 to 24 hours) vary with the atmospheric conditions of temperature and humidity and with the amount of moisture on the skin. Depending on their severity, skin burns can limit or entirely prevent movement of the limbs or of the entire body.

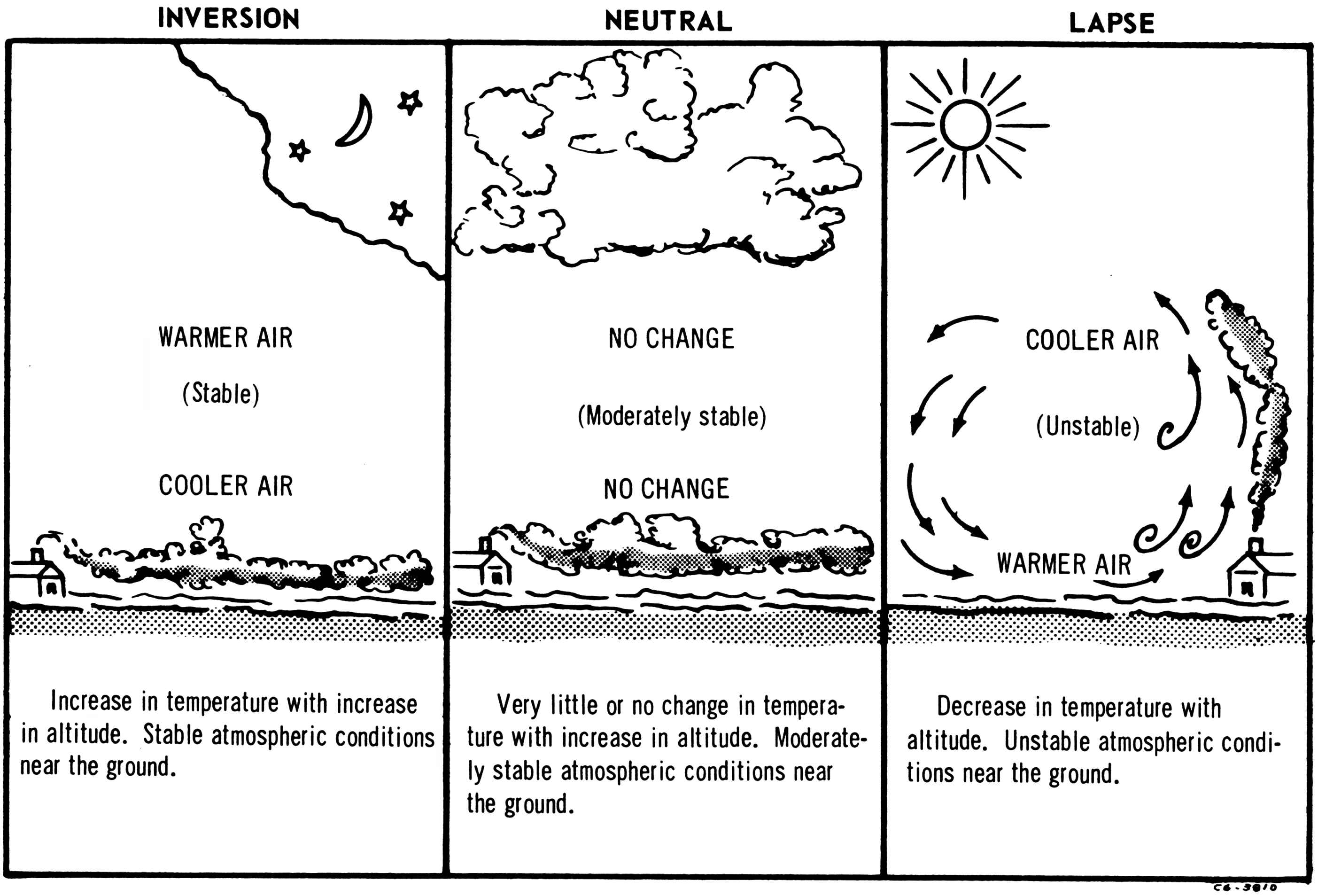


Figure 2. Temperature gradients.

Surprise dosage GB attacks are influenced only slightly by the temperature gradient except when made with the spray tank. Downwind vapor hazards to both enemy and friendly forces will be most significant during inversion and neutral conditions. Employment of VX is not affected by the temperature gradient.

Temperature gradients	Time
1. Inversion	From sunset to sunrise.
2. Neutral	2 hours before sunset to sunset, sunrise to 2 hours after sunrise, or any time windspeed is 15 kmph or greater.
3. Lapse	2 hours after sunrise to 2 hours before sunset.

Figure 3. Estimated times that temperature gradients will prevail. (Use when meteorological data are not available.)

(3) When actual or predicted meteorological conditions are not available for a target analysis, 70° F is used for temperature, 9 kmph is used as windspeed, and the temperature gradient is approximated from figure 3.

d. Windspeed and Direction.

(1) Air moving over the earth's surface sets up eddies, or mechanical turbulences, that act to dissipate a chemical cloud. A condition of calm will limit the merging of the individual gas clouds. Both of these conditions may reduce the effectiveness of a chemical agent attack. High winds increase the rate of evaporation of HD and dissipate chemical clouds more rapidly than low winds. Moderate winds are desirable for chemical employment. Large-area nonpersistent chemical attacks are most effective in winds not exceeding 28 kmph. Small-area nonpersistent chemical attacks with rockets or shell are most effective in winds not exceeding 9 kmph. However, if the concentration of chemical agent can be established quickly, the effects of high windspeed can be partially offset.

CHAPTER 4
EMPLOYMENT OF BIOLOGICAL AGENTS

1. General

a. Antipersonnel biological agents are micro-organisms that produce disease in man. These agents can be used to incapacitate or kill enemy troops through disease. They may cause large numbers of casualties over vast areas and could require the enemy to use many personnel and great quantities of supplies and equipment to treat and handle the casualties. Many square kilometers can be effectively covered from a single aircraft or missile. The search capability of biological agent clouds and the relatively small dose required to cause infection among troops give biological munitions the capability of covering large areas where targets are not precisely located.

b. A biological attack can occur without warning since biological agents can be disseminated by relatively unobtrusive weapon systems functioning at a considerable distance from the target area and relying upon air movement to carry the agent to the target.

c. Biological agents do not produce effects immediately. An incubation period is required from the time the agent enters the body until it produces disease. Some agents produce the desired casualty levels within a few days, whereas others may require more time to produce useful casualty levels. A variety of effects may be produced, varying from incapacitation with few deaths to a high percentage of deaths, depending on the type of agent.

2. Methods of Dissemination

a. The basic method of disseminating antipersonnel biological agents is the generation of aerosols by explosive bomblets and spray devices. Because exposure to sunlight increases the rate at which most biological agent aerosols die and thereby reduces their area coverage, night is the preferable time for most biological attacks. However, if troop safety is a problem, an attack may be made near sunrise to reduce the distance downwind that a hazard to friendly forces will extend. Conversely, to extend the downwind cloud travel and the area coverage from spray attack, a biological agent may be employed soon after sundown.

b. Missile-delivered Biological Munitions. Missile-delivered biological munitions are used for attack of large-area targets. A typical biological missile system consists of the following components:

(1) A missile vehicle and its launching equipment.

(2) A warhead that can be opened at a predetermined height to release biological bomblets over the target area. The warhead is shipped separately for assembly to a missile at the launching site.

(3) A warhead shipping container equipped with a heating-cooling element and a temperature control unit.

(4) Biological bomblets consisting of an agent container and a central burster that functions on impact. The bomblets have vanes that cause them to rotate in flight, thereby achieving lateral dispersion during their free fall and resulting in random distribution as a circular pattern.

c. Aircraft Spray Tank. Biological agents released from an aircraft spray tank cover a large area downwind of the line of release. A typical spray tank consists of the following components:

(1) An agent reservoir section that is shipped separately in an insulated shipping and storage container equipped with a heating-cooling element and a temperature control unit.

(2) A discharge nozzle assembly that can be mechanically adjusted to vary the agent flow rate.

Table 1. Chemical Weapons Data

1	2	3	4	5	6	7	8	9	10	11	12	13
Delivery system	Range (meters)		Agent	Munition	No of weapons per delivery unit	Weapon rate of fire	RT max (meters)[1 2]					Reference (table)
							Fire unit	Total dosage Casualty threat		Surprise dosage Casualty threat		
	Min	Max						10%	30%	10%	30%	
4.2-in mortar	180	4,500	HD	Cartridge, M2A1	4/Plat	50 rd/3 min 105 rd/15 min						18 19
105-mm howitzer		11,100	GB	Cartridge, M360	6/btry	5 rd/30 sec	1 btry[3]	200	100	100	50	2
						30 rd/3 min	1 bn[3]	300	300	200	100	3
			HD	Cartridge, M60		66 rd/15 min						18 19
155-mm howitzer		14,600	GB	Projectile, M121	6/btry	2 rd/30 sec	1 btry[3]	300	200	100	0	4
						12 rd/3 min	1 bn[3]	500	400	300	100	5
			HD	Projectile, M110		24 rd/15 min						18 19
			VX[4]	Projectile, M121			1 btry[3]	400	200	NA	NA	13
							1 bn[3]	500	400			
8-in howitzer		16,800	GB	Projectile, M426	4/btry	1 rd/30 sec	1 btry[3]	300	200	200	0	6
						4 rd/3 min	1 bn[3]	500	400	300	100	7
			VX[4]			10 rd/15 min	1 btry[3]	400	200	NA	NA	14
							1 bn[3]	500	400			
115-mm multiple rocket launcher, M91	2,740	10,600	GB[4]	Rocket, M55 (THE BOLT)		45 rkt/lchr/15 sec	1 lchr	1,000	750	500	200	8
							3 lchr	1,000	1,000	750	400	
							6 lchr	1,000	1,000	1,000	750	
							9 lchr	1,000	1,000	1,000	1,000	
			VX[4]				1 lchr	300	0	NA	NA	15
							3 lchr	750	300			
							6 lchr	1,000	400			
							9 lchr	1,000	750			
762-mm rocket, Honest John	8,500	38,000	GB[4]	Warhead, M190 (M139 bomblets)	2/btry	2 rkt/lchr/hr	1 lchr	600	600	600	400	9
							2 lchr	600	600	600	400	
Sergeant missile	46,000	139,000	GB[4]	Warhead, M212 (M139 bomblets)	2/bn	2 msl/lchr/hr	1 msl	600	400	600	200	10
							2 msl	600	600	600	400	
Aircraft	Dependent on type aircraft		GB[4]	Bomb, MC-1, 750-lb		Dependent on type aircraft	1 bomb	50				11
							6 bombs	300	200	300	50	
							12 bombs	500	300	400	200	
							24 bombs	500	300	500	300	
			GB[4]	Spray tank, 100-gal			1 spray tank	RT max=750 meters (one-half effective spray release line length)				12
							2 spray tanks					
			VX[4]				1 spray tank	RT max=500 meters (one-half effective spray release line length)				16
			BZ[4]	Bomb, 150-lb								17
				Bomb, 700-lb								

[1]RT max is largest target radius for which indicated casualty threat is tabulated for appropriate fire unit. Division of target into subtargets NOT considered.

[2]All windspeeds, temperature gradients, and protection categories considered.

[3]RT max computed for maximum number of volleys for which data are tabulated.

[4]Weapon system capabilities derived from tables composed of hypothetical data for INSTRUCTIONAL PURPOSES ONLY at the U. S. Army Command and General Staff College. For actual data, refer to FM 3-10.

Table 2. Estimated Fractional Casualty Threat From 105-mm Howitzer, GB Projectile, Battery Fire[1 2]

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Target radius–radius of effect (meters)	Range to target (km)	No of volleys	Windspeed[3]											
			4 kmph				9 kmph				28 kmph			
			Surprise[4]	Total dose[5]			Surprise[4]	Total dose[5]			Surprise[4]	Total dose[5]		
				I	N	L		I	N	L		I	N	L
50	<7.5	1	.10	.25	.20	.15	.10	.15	.10	.10				
		2	.20	.45	.40	.30	.15	.30	.25	.20		.10	.05	.05
		3	.30	.60	.60	.35	.30	.50	.45	.30	.10	.20	.15	.10
		4	.30	.75	.70	.45	.30	.55	.45	.35	.10	.25	.20	.10
		5	.35	.90	.85	.55	.35	.60	.50	.40	.15	.30	.25	.15
	>7.5	1	.05	.15	.15	.10	.05	.10	.05	.05				
		2	.15	.30	.25	.15	.10	.20	.15	.10		.05	.05	
		3	.15	.30	.30	.25	.10	.20	.20	.15		.10	.05	.05
		4	.20	.40	.35	.25	.15	.30	.30	.15	.05	.15	.15	.05
		5	.25	.45	.45	.30	.25	.40	.35	.25	.10	.20	.20	.10
100	<7.5	1	.05	.15	.15	.10	.05	.10	.05	.05				
		2	.10	.30	.30	.15	.10	.20	.15	.10				
		3	.15	.40	.35	.20	.15	.25	.25	.15	.05	.10	.05	
		4	.15	.40	.35	.30	.15	.30	.30	.15	.05	.10	.10	.05
		5	.20	.45	.40	.35	.20	.35	.35	.20	.10	.15	.15	.10
	$\geq$7.5	1	.05	.10	.10	.05		.05	.05					
		2	.10	.20	.20	.10	.05	.15	.10	.05				
		3	.10	.25	.25	.15	.10	.15	.15	.10		.05	.05	
		4	.10	.30	.25	.20	.10	.25	.20	.15		.10	.05	
		5	.15	.35	.30	.25	.15	.30	.25	.15	.05	.15	.10	.05
200	Any	1		.05	.05									
		2		.10	.10	.05		.05	.05					
		3	.05	.15	.15	.05		.10	.05					
		4	.05	.15	.15	.10		.10	.10					
		5	.05	.20	.20	.10	.05	.15	.10	.05				

[1]Blank spaces indicate fractional casualties are below 0.05.

[2]If the target is predominately wooded, use a windspeed of 4 kmph and neutral temperature gradient for total dose attack; use a windspeed of 4 kmph for surprise attack.

[3]For windspeeds other than those shown, use data given for the nearest windspeed.

[4]Multiply the figures given in the table by the appropriate factor to obtain the fractional casualties from surprise dose attack:

Troops in open foxholes:	0.7
Troops in covered foxholes or bunkers:	0.6

[5]I=inversion, N=neutral, L=lapse.

Table 17. BZ Munitions Requirements

1	2	3	4	5	6
Munition	Casualty level[2]	Area coverage[1] (square kilometers)			
		Windspeed[3]			
		8 kmph		16 kmph	
		Temperature gradient		Temperature gradient	
		Inversion	Neutral	Inversion	Neutral
150-lb bomb	.40	.05	.02	.03	.01
	.75	.03	.01	.02	.009
700-lb bomb	.40	.20	.07	.09	.04
	.75	.10	.04	.05	.03

[1]Area coverages are for one bomb.

[2]Casualty levels are for personnel without masks available. For personnel with masks available, multiply casualty levels by 0.7.

[3]For windspeeds other than those shown, use data given for the nearest windspeed.

NOTE: The above table is composed of hypothetical munitions and data for INSTRUCTIONAL PURPOSES ONLY at the U. S. Army Command and General Staff College. For actual data, refer to FM 3-10.

Table 18. HD Ammunition Expenditure for Vapor Effect (50 Percent Coverage of Target Area)[1 2]

Rounds required per hectare

Desired effect[3]	Exposure time (hours) — Temperature (°F)				4.2-inch mortar (cartridge M2A1) — Windspeed (kmph) 6			9			15			26		
	55°	70°	85°	100°	I	N	L	I	N	L	I	N	L	I	N	L
Cause eye irritation to troops without masks.	1	½	¼	⅛	10	14	16	11	21	22	15	22	26	20	24	29
	2	1	½	¼	6	8	9	8	12	14	12	13	16	17	21	24
	4	2	1	½	6	6	8	8	9	10	9	10	13	13	16	20
	8	4	2	1	4	6	6	6	8	9	8	9	11	12	13	15
	16	8	4	2	4	5	5	5	8	9	8	8	10	10	11	13
Disable masked troops (sweating in humid weather).	1	½	¼	⅛	35	46	52	39	53	63	46	63	80	59	77	108
	2	1	½	¼	20	29	33	24	35	40	30	45	56	41	59	69
	4	2	1	½	15	21	24	17	27	33	24	35	42	30	47	65
	8	4	2	1	11	17	18	13	21	26	17	28	38	27	45	63
	16	8	4	2	9	14	16	11	18	22	16	24	33	24	42	58
Disable masked troops (dry weather).	1	½	¼	⅛	64	83	95	72	95	114	86	113	144	108	144	198
	2	1	½	¼	36	52	58	44	62	72	57	81	101	71	120	125
	4	2	1	½	26	35	41	30	46	56	45	62	76	57	86	119
	8	4	2	1	18	27	30	23	35	44	32	50	68	50	81	114
	16	8	4	2	13	21	26	18	30	40	29	46	60	42	72	108

Desired effect[3]	Exposure time (hours) — Temperature (°F)				105-mm howitzer (cartridge M60) — Windspeed (kmph) 6			9			15			26		
	55°	70°	85°	100°	I	N	L	I	N	L	I	N	L	I	N	L
Cause eye irritation to troops without masks.	1	½	¼	⅛	22	24	27	24	34	39	39	44	46	32	53	65
	2	1	½	¼	18	22	23	20	22	27	29	32	34	26	39	51
	4	2	1	½	16	17	20	17	18	20	20	22	24	22	29	39
	8	4	2	1	12	15	17	13	12	17	15	20	22	18	27	36
	16	8	4	2	10	12	13	10	11	15	12	17	20	15	24	34
Disable masked troops (sweating in humid weather).	1	½	¼	⅛	70	83	108	77	95	121	95	123	166	108	157	243
	2	1	½	¼	42	54	63	47	63	84	66	89	102	82	108	192
	4	2	1	½	27	36	45	32	47	62	48	64	84	64	88	162
	8	4	2	1	18	29	34	24	38	47	33	53	76	54	83	138
	16	8	4	2	15	23	27	18	32	42	30	51	66	48	72	120
Disable masked troops (dry weather).	1	½	¼	⅛	128	154	174	144	174	212	189	...	...	202	...	...
	2	1	½	¼	75	98	128	89	113	147	111	156	180	148	198	288
	4	2	1	½	50	64	81	59	86	111	88	118	153	117	165	256
	8	4	2	1	33	50	58	45	65	84	62	95	138	101	154	240
	16	8	4	2	26	39	45	34	56	72	54	84	120	84	132	193

Desired effect[3]	Exposure time (hours) — Temperature (°F)				155-mm howitzer and gun (projectiles M110 and M104) — Windspeed (kmph) 6			9			15			26		
	55°	70°	85°	100°	I	N	L	I	N	L	I	N	L	I	N	L
Cause eye irritation to troops without masks.	1	½	¼	⅛	8	10	10	9	11	12	10	12	13	11	14	16
	2	1	½	¼	6	8	9	8	10	11	9	11	12	10	12	14
	4	2	1	½	4	5	6	6	8	9	8	9	10	9	10	12
	8	4	2	1	4	5	5	5	6	8	6	8	9	8	9	11
	16	8	4	2	4	4	4	4	5	6	5	6	8	5	8	10
Disable masked troops (sweating in humid weather).	1	½	¼	⅛	20	28	30	23	32	36	26	39	44	32	46	58
	2	1	½	¼	12	17	20	15	22	24	18	27	34	24	36	46
	4	2	1	½	10	13	16	11	18	20	15	20	27	18	29	33
	8	4	2	1	6	10	12	9	13	16	12	17	24	16	23	33
	16	8	4	2	5	9	11	8	11	15	11	15	22	15	20	29
Disable masked troops (dry weather).	1	½	¼	⅛	36	48	53	41	56	63	46	66	78	59	83	105
	2	1	½	¼	21	28	33	26	36	41	38	54	63	42	65	84
	4	2	1	½	15	21	26	18	28	33	26	36	45	33	50	66
	8	4	2	1	11	16	18	13	21	26	22	33	40	28	42	56
	16	8	4	2	9	12	15	11	18	21	18	30	36	24	38	46

Temperature gradient[4]

[1]For open terrain. For heavily wooded terrain or jungle, multiply the figure obtained by 0.5 to obtain the appropriate expenditure.

[2]Blank spaces indicate excessive expenditures.

[3]An average of 50 percent casualties is expected among all troops who remain in the target area for the times specified.

[4]I = inversion, N=neutral, L=lapse.

[redacted]

S/C

DEPARTMENT OF THE ARMY FIELD MANUAL	FM 3–10B
NAVAL WARFARE INFORMATION PUBLICATION	NWIP 36–4
DEPARTMENT OF THE AIR FORCE MANUAL	AFM 355–9
MARINE CORPS MANUAL	FMFM 11–3B

EMPLOYMENT OF CHEMICAL AGENTS (U)

This copy is a reprint which includes current pages from Changes 1.

[redacted]

[redacted]

DEPARTMENTS OF THE ARMY, THE NAVY AND THE AIR FORCE

NOVEMBER 1966

[redacted]

CHAPTER 1
INTRODUCTION

Section I. GENERAL

1. (U) Purpose

This manual provides classified data on chemical agents and on the capabilities and effects of chemical munitions. When used in conjunction with its unclassified counterpart, FM 3-10/NWIP 36-2/AFM 355-4/FMFM 11-3, Employment of Chemical and Biological Agents, it provides guidance in planning the employment of chemical munitions.

2. (U) Scope

This manual contains classified data on lethal agents VX and GB and incapacitating agent BZ; munitions effects tables; and predicted effects of ground-fired and air-released munitions utilized to disseminate these agents. As a joint publication, it discusses all appropriate chemical munitions of the U.S. Army, Navy, Air Force, and Marine Corps. Unclassified HD chemical munitions expenditure tables and guidance in chemical target analysis and casualty estimation are given in FM 3-10/NWIP 36-2/AFM 355-4/FMFM 11-3.

3. (U) Reliability

Data contained in this manual are based on proving ground tests and field tests, analytical studies of such data, and predictions extrapolated from mathematical models.

4. (U) Army, Navy, Air Force, and Marine Corps User Comments

Users of this manual are encouraged to submit recommended changes or comments to improve the manual. Comments should be keyed to the specific page, paragraph, and line of the text in which the change is recommended. Reasons for each comment should be provided to insure understanding and complete evaluation. Comments should be forwarded direct to the Commanding Officer, U.S. Army Combat Developments Command CBR Agency, Fort McClellan, Ala. 36205, with an information copy to the cognizant service doctrinal development agency.

Section II. ANTIPERSONNEL CHEMICAL AGENTS

6. (U) Incapacitating Agent BZ

This agent is disseminated as an aerosol to produce physical and mental effects when inhaled. The effects are temporary, and recovery is normally complete. There may be permanent ill effects in a few instances among the very young, the aged, and the infirm, or when massive dosages are received.

a. Tactical Employment. BZ is employed against carefully selected targets to incapacitate enemy troops when the use of lethal or destructive munitions is undesirable. This agent may be particularly useful in situations where adequate protective equipment is normally not available to enemy troops or where the status of training or mask discipline is poor, such as in counterinsurgency operations.

b. Limitations. BZ has the following limitations:

(1) The white agent cloud produced by pyrotechnic mixtures acts as a visible alarm.

(2) BZ may be defeated by improvised respiratory protection such as a folded cloth over mouth and nose.

(3) The effects are not immediate but require an average onset time of about 3 to 6 hours.

(4) There is no known antidote to treat affected friendly personnel.

c. Median Incapacitating Dosage (ICt_{50}). This is about 110 mg-min/m^3 for man engaged in mild activity (breathing rate of 15 liters/min).

d. Physiological and Psychological Symptoms. The symptoms listed below will become more intense as the dosage received increases. They also vary according to the inherent characteristics of each individual exposed to the agent. Because of the many variables involved, estimation of the percentage and type of casualties produced from a BZ attack is difficult. Approximations for the occurrence of ultimate casualties among unmasked personnel are 5 percent in 2 hours, 50 percent in 4½ hours, and 95 percent in 9½ hours.

(1) Symptoms likely to appear in 30 minutes to 3 hours: dizziness, extreme drowsiness, dryness of the mouth, and increased heartbeat.

(2) Symptoms likely to appear in 3 to 5 hours: restlessness, involuntary muscular movement, near vision impairment, and physical incapacitation.

(3) Symptoms likely to appear in 6 to 10 hours: hallucinations, lack of muscular coordination, disorientation, and difficulty in memory recall.

e. Duration of Incapacitation. The duration of incapacitation varies with the dosage received—from 24 hours to 5 days.

f. Duration of Effectiveness. Under average meteorological conditions in the open, the aerosol is normally effective for only a few minutes after dissemination, since the fine BZ particles travel

[redacted]

27. (U) CBU-5B/M43 750-Pound BZ Cluster Bomb

Both the U.S. Air Force CBU-5B and the U.S. Army M43 750-pound cluster bombs contain 57 M138 BZ-filled bomblets. The U.S. Army M43 cluster is designed for delivery by aircraft at low speeds. When modified and equipped with a suitable fairing for streamlining purposes, an internal arming wire system, and a strengthened tail fin, it is then designated the CBU-5B and can be delivered by high-performance aircraft.

a. Operational Concepts. The BZ cluster bomb is used on carefully selected targets against enemy personnel when the use of lethal chemical or destructive weapon systems is militarily or politically undesirable. See paragraph 6 for additional data.

b. Characteristics. The cluster contains about 85 pounds of agent BZ and employs two tail mechanical time fuzes. To function properly, the cluster must be released above 6,200 feet so as to allow the cluster to open at approximately 4,500 feet. The M138 bomblet contains four canisters, each with three-fourth pound of agent-pyrotechnic mixture (50/50 ratio), and an "all-ways" impact fuze. The bomblet is *not* self-dispersing.

c. Capabilities. The cluster delivers M138 bomblets over an elliptical impact area having a cross section of approximately 100 by 200 meters when released at heights above 6,200 feet. One cluster can cover about 12,000 square meters (1.2 hectares) with an incapacitating total dosage of BZ (110 mg-min/m^3) under neutral temperature gradient and in a wind speed between 2 and 10 knots; under lapse temperature gradient conditions, the area coverage will be smaller. Under optimum delivery conditions, the area coverage for one cluster is expected to range from 15,000 to 20,000 square meters. Field tests indicate that wind speed has only minor effects upon area coverage.

d. Operational Considerations. Refer to the appropriate technical order/flight manual to determine aircraft loads (see para 16*d*).

[redacted]

Field Manual
No 3-6

Air Force Manual
No 105-7

Fleet Marine Force Manual
No. 7-11-H

HEADQUARTERS
DEPARTMENT OF THE ARMY
DEPARTMENT OF THE AIR FORCE
UNITED STATES MARINE CORPS
Washington, DC, 3 November 1986

FIELD BEHAVIOR OF NBC AGENTS (INCLUDING SMOKE AND INCENDIARIES)

Table of Contents

DISPERSION CATEGORY	ATMOSPHERIC DESCRIPTION	TRADITIONAL ATMOSPHERIC CONDITIONS
1	Very Unstable	Lapse
2	Unstable	Lapse
3	Slightly Unstable	Neutral
4	Neutral	Neutral
5	Slightly Stable	Neutral
6	Stable	Inversion
7	Extremely Stable	Inversion

Figure 1-1. Atmospheric stability categories and conditions.

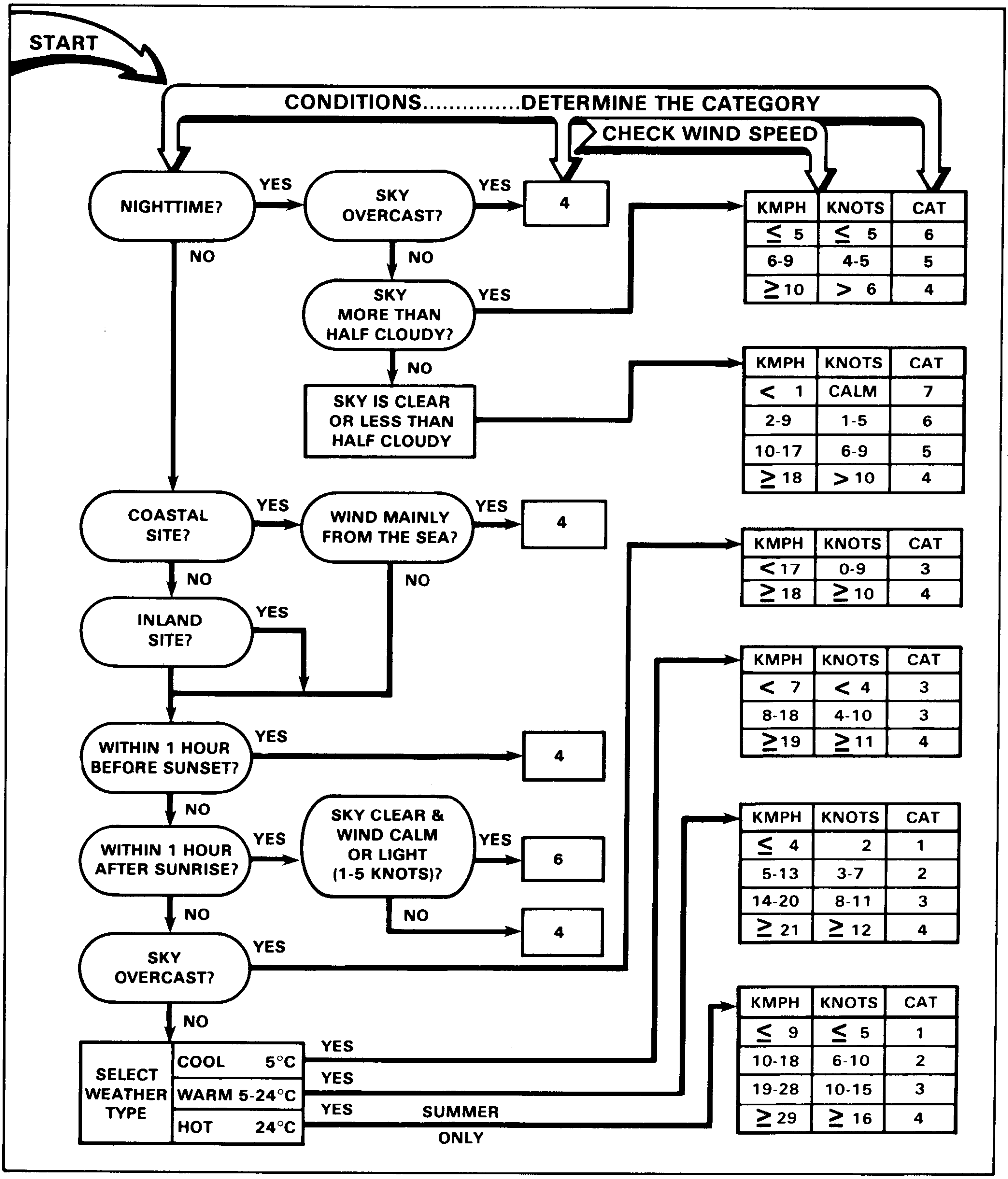


Figure 1-2. Stability decision tree.

Page 1-14 states that the mixed air layer height is 50-100 m on a clear, calm night, just before 400 m before sunrise, and 2 km on a hot summer day

Table 1-3. Center line dosages at different distances downwind for different dispersion categories and wind speeds for a unit source. 100 kilograms of GB

Stability Category	Wind Speed	DOWNWIND DISTANCE IN KM							
		.5	1	2	4	6	10	20	30
		DOSAGES (mg-min/M³)							
1	1	57.82	10.960	2.4820	1.2070	.8048	.48290	.24140	.16100
1	3	19.15	3.628	.8224	.3998	.2665	.15990	.07995	.05330
1	5	11.47	2.174	.4928	.2396	.1597	.09582	.04791	.03194
2	3	65.93	16.480	4.121	1.0300	.4671	.22840	.11360	.07575
2	6	32.86	8.215	2.054	.5135	.2328	.11380	.05663	.03775
2	10	19.75	4.938	1.235	.3087	.1400	.06843	.03404	.02269
3	3	172.60	46.26	12.400	3.321	1.5370	.5825	.18010	.11510
3	7	73.86	19.79	5.302	1.421	.6576	.2492	.07703	.04925
3	12	43.09	11.55	3.094	.829	.3837	.1454	.04494	.02874
4	3	572.4	170.20	50.590	15.040	7.398	3.0260	.8997	.44450
4	8	213.9	63.61	18.910	5.622	2.765	1.1310	.3363	.16620
4	16	107.1	31.84	9.467	2.814	1.384	.5662	.1683	.08318
5	2	1,837.0	606.0	199.90	65.94	34.470	15.220	5.021	2.6250
5	5	736.2	242.9	80.12	26.43	13.810	6.101	2.012	1.0520
5	9	408.7	134.8	44.47	14.67	7.668	3.387	1.117	.5839
6	1	10,080.0	3,691.0	1,351.0	494.50	274.70	131.00	47.930	26.630
6	3	3,339.0	1,222.0	447.4	163.80	90.96	43.37	15.870	8.818
6	5	2,001.0	732.4	268.1	98.12	54.51	25.99	9.5120	5.284
7	HIGHER DOSAGES THAN ABOVE								

Table 1-4. Summary of favorable and unfavorable weather and terrain conditions for tactical employment of chemical agent vapor or aerosol. (The stability condition listed for the south slope is for the northern hemisphere; due to solar loading on the slope, the situation would be reversed for the southern hemisphere.)

FACTOR	UNFAVORABLE	MODERATELY FAVORABLE	FAVORABLE
Wind	Artillery employment if speed is more than 7 knots. Aerial bombs if speed is more than 10 knots.	Steady, 5 to 7 knots, or land breeze.	Steady, less than 5 knots, or sea breeze.
Dispersion Category	Unstable (lapse).	Neutral.	(Stable) inversion.
Temperature	Less than 4.4°C.	4.4° to 21.1°C.	More than 21.1°C.
Precipitation	Any.	Transitional.	None.
Cloud Cover	Broken, low clouds during daytime. Broken, middle clouds during daytime. Overcast or broken, high clouds during daytime. Scattered clouds of all types during daytime. Clouds of vertical development.	Thick, low overcast. Thick, middle overcast.	Broken, low clouds at night. Broken, middle clouds at night. Overcast or broken, high clouds at night. Scattered clouds of all types at night. Clear sky at night.
Terrain	Hilltops, mountain crests. South slopes* during daytime.	Gently rolling terrain. North slopes at night.	Even terrain or open water.
Vegetation*	Heavily wooded or jungle.	Medium dense.	Sparse or none.

*Cloud dissemination occurs above the canopy.

Chemical and biological contamination avoidance, FM 3-3 (1992)

10 grams/square meter

TABLE 1-2. Chemical Agent Persistency in Hours on CARC Painted Surfaces.

Temperature		GA/GF[1]	GB[2,3]	GD[2,3]	HD[1]	VX[2,3]
C°	F°					
-30	-22	*	110.34	436.69	**	***
-20	-4	*	45.26	145.63	**	***
-10	14	*	20.09	54.11	**	***
0	32	*	9.44	22.07	**	***
10	50	1.42	4.70	9.78	12	1776
20	68	0.71	2.45	4.64	6.33	634
30	86	0.33	1.35	2.36	2.8	241
40	104	0.25	0.76	1.25	2	102
50	122	0.25	0.44	0.70	1	44
55	131	0.25	0.34	0.51	1	25

NOTE

1 For grassy terrain multiply the number in the chart by 0.4.

2 For grassy terrain multiply the number in the chart by 1.75.

3 For sandy terrain multiply the number in the chart by 4.5.

* Agent persistency time is less than 1 hour.

** Agent is in a frozen state and will not evaporate or decay.

*** Agent persistency time exceeds 2,000 hours.

U.S. ARMY COMMAND AND GENERAL STAFF COLLEGE
Fort Leavenworth, Kansas, *25 July 1983*

CHEMICAL WEAPONS EMPLOYMENT DATA

Page

CHAPTER 1

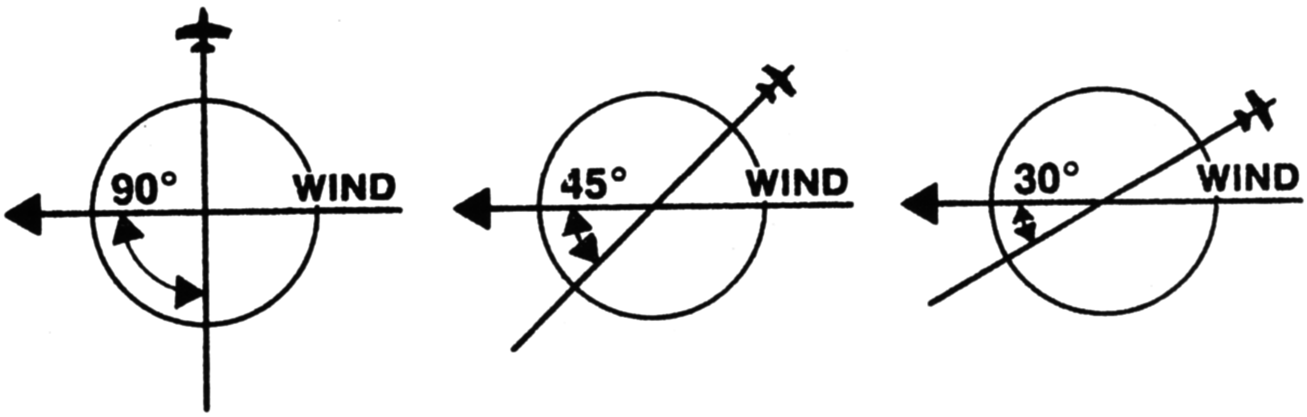
*This reference book replaces RB 3—2, 8 July 1981, for all resident and nonresident programs.

Section X
Spray Tank/VX

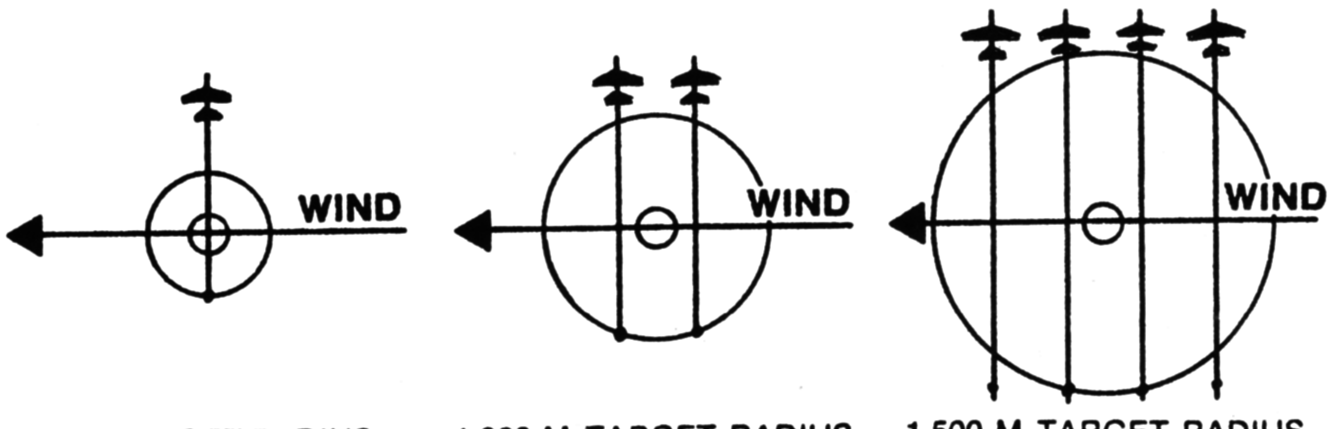
AIM POINT & FLIGHT PATH ADJUSTMENTS
VARIABLE DELIVERY TECHNIQUES

DELIVERY SYSTEM	**TANKS/AIRCRAFT**	**AIRCRAFT SPEED***
Refer to Air Force & Navy Publications	Minimum 1 Maximum 2	450 Knots Centered Delivery

$$\textbf{Altitude of Spray Release Line} = \frac{\textbf{Windspeed - Height Product (VWH)}}{\textbf{Windspeed in Knots}}$$



FLIGHT PATH IN RELATION TO WIND DIRECTION



500-M TARGET RADIUS 1,000-M TARGET RADIUS 1,500-M TARGET RADIUS

Flight path Initiation point is leading edge of target Target center

**Used on all tables in this section.*

Table I-79. Spray Tank/VX Aim Point & Flight Path Adjustments

PROTECTION CATEGORY: A (NO MASK OR PROTECTIVE CLOTHING)
CASUALTIES WITHIN: 1/2 HOUR

FLOW RATE	WIND ANGLE	TARGET RADIUS (Meters)	WINDSPEED-HEIGHT PRODUCT (VWH) 500 NO. AIRCRAFT			750 NO. AIRCRAFT			1000 NO. AIRCRAFT			2000 NO. AIRCRAFT			3000 NO. AIRCRAFT		
			1	2	4	1	2	4	1	2	4	1	2	4	1	2	4
ONE TANK AT HALF FLOW	90°	500	.06	.15	.20	.17	.37	.60	.25	.46	.68	.25	.43	.60	.19	.35	.50
		1000	.01	.04	.10	.06	.15	.31	.09	.19	.45	.09	.20	.45	.09	.20	.45
		1500	–	.02	.07	–	.06	.14	–	.06	.19	–	.06	.22	–	.08	.23
	45°	500	.04	.11	.23	.13	.29	.61	.20	.41	.69	.22	.41	.64	.21	.37	.57
		1000	.01	.04	.11	.04	.10	.23	.07	.16	.36	.08	.19	.42	.08	.19	.42
		1500	–	–	.07	–	.06	.12	–	.08	.18	–	.08	.20	–	.08	.22
	30°	500	.02	.07	.16	.10	.23	.48	.15	.32	.64	.17	.36	.62	.18	.35	.57
		1000	–	.03	.08	.03	.09	.20	.06	.13	.29	.07	.15	.34	.07	.16	.36
		1500	–	–	.04	–	.04	.09	–	.06	.14	–	.08	.18	–	.08	.20
TWO TANKS AT HALF FLOW	90°	500	.08	.17	.30	.22	.46	.69	.34	.55	.69	.31	.50	.65	.25	.43	.60
		1000	.01	.05	.11	.10	.19	.41	.13	.29	.61	.15	.33	.53	.18	.35	.51
		1500	.01	.03	.10	.05	.11	.25	.07	.17	.38	.09	.20	.46	.09	.22	.49
	45°	500	.06	.13	.28	.18	.37	.71	.27	.50	.71	.30	.50	.67	.29	.47	.62
		1000	.02	.06	.13	.06	.14	.31	.11	.24	.51	.13	.29	.60	.15	.32	.63
		1500	–	.02	.08	.03	.09	.20	.06	.14	.31	.07	.17	.38	.08	.19	.42
	30°	500	.04	.09	.39	.13	.29	.73	.20	.41	.69	.23	.44	.63	.24	.43	.57
		1000	.01	.04	.10	.05	.11	.26	.09	.19	.41	.10	.23	.51	.12	.26	.56
		1500	–	.01	.06	.02	.07	.14	.04	.11	.24	.06	.13	.29	.07	.15	.34

PROTECTION CATEGORY: A (NO MASK OR PROTECTIVE CLOTHING)
CASUALTIES WITHIN: 1 HOUR

FLOW RATE	WIND ANGLE	TARGET RADIUS (Meters)	WINDSPEED-HEIGHT PRODUCT (VWH) 500 NO. AIRCRAFT			750 NO. AIRCRAFT			1000 NO. AIRCRAFT			2000 NO. AIRCRAFT			3000 NO. AIRCRAFT		
			1	2	4	1	2	4	1	2	4	1	2	4	1	2	4
ONE TANK AT HALF FLOW	90°	500	.08	.20	.27	.25	.50	.70	.36	.57	.69	.33	.53	.64	.28	.48	.58
		1000	.02	.06	.15	.10	.22	.47	.16	.34	.65	.19	.39	.65	.22	.40	.63
		1500	–	.04	.09	–	.10	.23	–	.12	.34	–	.15	.41	–	.21	.42
	45°	500	.06	.14	.30	.19	.40	.71	.28	.52	.72	.31	.52	.68	.30	.49	.64
		1000	.02	.06	.14	.07	.15	.33	.11	.25	.52	.14	.29	.55	.16	.32	.54
		1500	–	.02	.07	–	.08	.19	–	.13	.34	–	.16	.38	–	.19	.43
	30°	500	.04	.10	.22	.14	.30	.63	.21	.43	.69	.24	.45	.65	.25	.45	.59
		1000	.01	.04	.10	.05	.12	.27	.09	.19	.41	.10	.23	.48	.12	25	.49
		1500	–	.01	.05	–	.06	.14	–	.11	.24	–	.14	.31	–	.16	.37
TWO TANKS AT HALF FLOW	90°	500	.11	.24	.41	.32	.57	.74	.39	.59	.72	.35	.55	.69	.29	.47	.66
		1000	.03	.08	.19	.13	.28	.58	.21	.43	.72	.27	.49	.71	.31	.51	68
		1500	.01	.05	.14	.07	.16	.37	.12	.26	.56	.16	.34	.66	.19	39	.67
	45°	500	.08	.17	.37	.23	.48	.75	.35	.57	.72	.35	.55	.68	.32	.51	.65
		1000	.03	.08	.17	.09	.20	.42	.16	.34	.67	.20	.42	.71	.24	.47	.71
		1500	.01	.03	.10	.05	.13	.28	.09	.20	.44	.12	.26	.55	.14	.30	60
	30°	500	.05	.13	.51	.17	.37	.74	.26	.50	.71	.28	.49	65	.28	.48	.64
		1000	.02	.05	.13	.07	.16	.34	.12	.26	.55	.16	.33	.67	.18	38	.69
		1500	–	.02	.07	.03	.10	.20	.07	.15	.35	.10	.19	.43	.10	23	.48

Table I-80. Spray Tank/VX Expected Fraction of Casualties

PROTECTION CATEGORY: **A** (NO MASK OR PROTECTIVE CLOTHING)
CASUALTIES WITHIN: **ULTIMATE**

FLOW RATE	WIND ANGLE	TARGET RADIUS (Meters)	WINDSPEED-HEIGHT PRODUCT (VWH)														
			500			750			1000			2000			3000		
			NO. AIRCRAFT			NO. AIRCRAFT			NO. AIRCRAFT			NO. AIRCRAFT			NO. AIRCRAFT		
			1	2	4	1	2	4	1	2	4	1	2	4	1	2	4
ONE TANK AT HALF FLOW		500	.14	.31	.43	.39	.62	.74	.39	.59	.69	.35	.55	.65	.30	.50	.60
	90°	1000	.05	.12	.26	.18	.38	.69	.30	.54	.73	.35	.56	.70	.36	.56	.68
		1500	--	.06	.15	--	.21	.42	--	.31	.56	--	.34	.59	--	.41	.59
		500	.10	.23	.49	.30	.56	.75	.39	.60	.72	.36	.56	.68	.33	.53	.65
	45°	1000	.04	.10	.22	.12	.26	.53	.19	.39	.63	.23	.43	.61	.26	.44	.59
		1500	--	.06	.12	--	.16	.33	--	.27	.54	--	.35	.62	--	.41	.65
		500	.07	.16	.36	.22	.45	.74	.30	.54	.69	.31	.52	.65	.30	.50	.60
	30°	1000	.03	.07	.16	.09	.20	.42	.14	.29	.55	.16	.34	.56	.18	.35	.55
		1500	--	.04	.09	--	.12	.25	--	.20	.45	--	.27	.55	--	.33	.59
TWO TANKS AT HALF FLOW		500	.18	.38	.64	.43	.64	.75	.39	.59	.73	.35	.55	.70	.30	.50	.67
	90°	1000	.06	.15	.30	.21	.45	.74	.35	.59	.73	.39	.60	.71	.39	.59	.69
		1500	.04	.09	.22	.13	.28	.60	.22	.46	.72	.30	.54	.74	.34	.56	.72
		500	.13	.28	.58	.35	.60	.75	.40	.61	.72	.36	.56	.68	.34	.53	.65
	45°	1000	.05	.11	.27	.16	.33	.66	.27	.52	.75	.33	.57	.73	.37	.59	.72
		1500	.03	.06	.16	.10	.21	.44	.16	.34	.65	.21	.42	.69	.24	.46	.68
		500	.09	.20	.72	.26	.51	.74	.33	.56	.74	.32	.53	.70	.31	.50	.67
	30°	1000	.04	.09	.20	.12	.26	.54	.20	.41	.73	.25	.49	.74	.29	.53	.73
		1500	.02	.04	.12	.07	.16	.32	.12	.25	.52	.15	.30	.60	.17	.34	.61

Table I-81. Spray Tank/VX Expected Fraction of Casualties

Section XI
HD Munitions

HD DOSAGE REQUIREMENTS

HD DOSAGES mg/minute/cubic meter			PERSONNEL PROTECTION CATEGORY	CASUALTY EFFECTS	DEGREE OF DISABILITY	ONSET TIME	DURATION
HOT[1]	WARM[2]	COOL[3]					
50	50	50	"A" no mask or protective clothing	No significant injury; maximum safe dosage	--	--	--
100	100	100		Eye damage of threshold military significance	PARTIAL	6-24 HR	1-3 DAYS
200	200	200		Temporary blindness	TOTAL	3-12 HR	2-7 DAYS
100	150	400	"B" or "C" with no protective clothing	No significant injury; maximum safe dosage	--	--	--
200	300	1,000		Skin burns of threshold military significance	PARTIAL	2-12 DAYS	1-2 WEEKS
500	1,000	2,000 to 4000		Severe genital burns	PARTIAL TO TOTAL	2-7 DAYS	1-4 WEEKS
750	2,000 to 4,000	4,000 to 10,000		Severe generalized burns	PARTIAL TO TOTAL	4-12 HRS About 24 HRS	3-4 WEEKS 1-2 WEEKS
			"D" mask with protective clothing	HD IS NOT RECOMMENDED FOR USE IN THIS PROTECTION CATEGORY.			

[1]Hot, humid; above 80°F; sweating skin
[2]Warm: 60°-80°F; skin not wet with sweat
[3]Cool: 40°-60°F; cool, dry skin

Table I-85. HD Munitions

HD Contamination Replenishment Time (Rate Factors)

TERRAIN FACTOR **X** WINDSPEED FACTOR **X** GROUND SURFACE TEMPERATURE FACTOR **X** TEMPERATURE GRADIENT FACTOR[2] (STABILITY) **=** TIME (HOURS) FOR 50% EVAPORATION OF HD

FACTORS

TERRAIN	WINDSPEED[1] (knots)	GROUND SURFACE TEMPERATURE (°F)	TEMPERATURE GRADIENT[2]
	1 = 3.1		
OPEN	2 = 1.8		INVERSION = 1.2
GRASSLAND = 1	3 = 1.3		
	4 = 1.0	50° = 4.0	
		60° = 2.5	
FOREST OR	5 = 0.8	70° = 1.6	NEUTRAL = 1.0
JUNGLE = 1	6 = 0.7	80° = 1.0	
	7 = 0.6	90° = 0.6	
	9 = 0.5	100° = 0.4	
	11 = 0.4	110° = 0.3	
		120° = 0.2	
BARREN SOIL	14 = 0.3		LAPSE = 0.7
OR SAND = 2	18 = 0.3		

[1]at 2 meters high in the open
[2]in the open

Table I-96. HD Contamination Replenishment Time (Rate Factors)

Approximate Duration of Hazard in Contaminated Terrain

TASK	TERRAIN	BLISTER AGENT (HD) TEMPERATURE[3] WARM (70°-85°F)	BLISTER AGENT (HD) TEMPERATURE[3] HOT (80°-100°F)	NERVE AGENT (VX-GB) UNIFORM[4] SUMMER	NERVE AGENT (VX-GB) UNIFORM[4] WINTER
		APPROXIMATE TIME AFTER CONTAMINATION THAT PRESCRIBED TASKS MAY BE PERFORMED WITH NEGLIGIBLE RISK[1] (Not wearing protective clothing)[2]			
		WEARING MASKS			
TRAVERSAL[5] (Walking across area 2 hours or less	Bare soil or low vegetation[6] (except sand)	36 HOURS	36 HOURS	5 HOURS	2 HOURS
	High vegetation, including jungle and heavy woods	4 DAYS	2 DAYS	28 HOURS	10 HOURS
		NOT WEARING MASKS[7]			
OCCUPATION (Without hitting ground 24 hours)	Bare soil or low vegetation[6] (except sand)	4 DAYS	3 DAYS	32 DAYS	13 DAYS
	High vegetation, including jungle and heavy woods	4 DAYS	3 DAYS	32 DAYS	13 DAYS
OCCUPATION (Involving advance under fire 24 hours)	Bare soil or low vegetation[6] (except sand)	4 DAYS	3 DAYS	32 DAYS	13 DAYS
	High vegetation including jungle and heavy woods	6 DAYS	4 DAYS	50 DAYS	18 DAYS

[1]These times are safe-sided for troop safety.
[2]Leather combat boots treated with protective dubbing or rubber combat boots are worn.
[3]Effects of blister agent vary significantly with temperature. Mustard freezes in temperatures below 60°F and can present a hazard when the temperature rises.
[4]Protection from V-agent and thickened G-agent varies significantly with layers of clothing worn.
[5]For personnel walking for 2 hours in an area contaminated by blister agents, the limiting factor is the vapor hazard. If only a few minutes are required for traversal of the area, the task can be initiated at earlier times than those given.
[6]Times shown are not applicable to sand, which will hold chemical agents for longer periods of time than those given.
[7]The data refer to approximate times at which personnel could occupy contaminated areas without having to wear protective masks for protection against vapor hazard.

Table I-97. Approximate Duration of Hazard in Contaminated Terrain

WARNING
This table is intended as a guide only.
Chemical agent detectors must be used to determine the extent of actual contamination and vapor hazards.

Table 5-2. Potential Biological Warfare Agents.

Microorganism	Mode of Transmission	Incubation Period (Days)[2]	Mortality Rate (Percent)2	Vaccine ([3])	Treatment ([4])
Bacteria					
Bacillus Anthracis (Anthrax)	A, D[9], I	1-7	5-1005	+	E[6]
Francisella Tularensis (Tularemia)	A, D[9], I, V	1-10	<30	+ +	E
Yersinia Pestis (Plague)	A, V	2-6	25-1007	+ + +	E[8]
Vibrio Cholerae (Cholera)	I	1-5	15-90	+ + +	E
Corynebacterium Diptheriae (Diptheria)	A, D[9]	2-5	5-12	+ + +	E
Salmonella Typhi (Typhoid Fever)	I	6-21	7-14	+ + +	E
Rickettsiae					
Rickettsia SPP (Spotted fevers group)	V	6-15	10-40	+ + +	E
Rickettsiae (Endemic or flea-borne typhus)	V	6-14	2-5	N	E
Rickettsia (Rocky Mountain spotted fever)	V	3-10	30 (approx)	N	E
Coxiella Burnetii (Q fever)	A, I	14-21	<1	+ +	E

[1] Transmission can be by aerosol-A, direct contact-D, ingestion-I, and/or vector-V.

[2] Incubation periods and mortality rates vary according to a number of factors (such as ability of the host to resist infection, infective dose, portal of entry, and virulence of the microorganism).

[3] + indicates vaccine available but of questionable value; + + indicates vaccine available, but mainly used in high risk individuals; + + + indicates vaccine used extensively; N indicates no vaccine available.

[4] E indicates effective treatment available; N indicates no specific treatment.

[5] The mortality rate is lower when the agent enters through the skin; higher when it enters through the respiratory tract.

[6] Treatment must be initiated in the earliest stage of the pulmonary form to be effective.

[7] The 25 percent represents mortality due to bubonic form; 100 percent represents mortality due to pneumonic form.

[8] Mosquitoes are thought to be the primary vectors, but this has not been proven.

[9] Direct contact refers to being bitten by a rabid animal, which is the usual means of transmission, or coming into contact with a rabid animal.

Table 5-2. Potential Biological Warfare Agents (continued).

Microorganism	Mode of Transmission	Incubation Period (Days)[2]	Mortality Rate (Percent)2	Vaccine ([3])	Treatment ([4])
Viruses					
Eastern Equine Encephalitis (EEE)	V[8]	4-24	60 (Approx)	N	N
Venezuelan Equine Encephalitis (VEE)	V[8]	4-24	<1	+ +	N
Japanese B Encephalitis	V (Mosquito)	5-15	10-80	+ +	N
Russian SpringùSummer Encephalitis (RSSE)	V (Tick)	7-14	3-40	+	N
Yellow Fever	V (Mosquito)	3-6	5-40	+ + +	N
Dengue Fever	V (Mosquito)	4-10	<1	+	N
Pox Virus					
Variloa Virus (Smallpox)	A, D[9]	7-16	10-25	+ + +	N
Hantaan Virus (Hemorrhagic Fever with Renal Syndrome)	A, V				
Phlebovirus (Rift Valley Fever)	V (Mosquito)	4-6	<1	N	N
Nairovirus (Crimean-Congo Hemorrnagil Fever)	V (Tick)	3-7			
Bunyavirus (LA Crosse)	V (Mosquito)				
Phlebovirus(Sandfly)	V (Sand fly)	3-6			

[1] Transmission can be by aerosol-A, direct contact-D, ingestion-I, and/or vector-V.
[2] Incubation periods and mortality rates vary according to a number of factors (such as ability of the host to resist infection, infective dose, portal of entry, and virulence of the microorganism).
[3] + indicates vaccine available but of questionable value; + + indicates vaccine available, but mainly used in high risk individuals; + + + indicates vaccine used extensively; N indicates no vaccine available.
[4] E indicates effective treatment available; N indicates no specific treatment.
[5] The mortality rate is lower when the agent enters through the skin; higher when it enters through the respiratory tract.
[6] Treatment must be initiated in the earliest stage of the pulmonary form to be effective.
[7] The 25 percent represents mortality due to bubonic form; 100 percent represents mortality due to pneumonic form.
[8] Mosquitoes are thought to be the primary vectors, but this has not been proven.
[9] Direct contact refers to being bitten by a rabid animal, which is the usual means of transmission, or coming into contact with a rabid animal.

Table 5-3. Threat Toxins.

Type of Toxin	Means of ID	Symptoms in Man	Effects on Man	Rate of Action	How Normally Disseminated	Protection Required	Decontamination
Mycotoxins	None	Vomiting, eye and skin irritation, dizziness, bloody diarrhea, and blisters.	Can incapacitate or kill, depending on concentration.	Rapid	Dusts, droplets, aerosols, smokes, or covert means	Protective mask and protective clothing	Soap and water, bleach, M258-series kit, STB and DS2
Enterotoxins	None	Severe vomiting and diarrhea, painful cramps, and weakness	Primarily incapacitates, assuming proper first aid is conducted	Same as above	Same as above	Same as above	Same as above
Botulinum Toxin	None	Double vision, weakness, difficulty in speech and swallowing, and respiratory paralysis	Kills	Delayed	Same as above	Same as above	Same as above

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Energy Division

Expedient Respiratory and Physical Protection: Does a Wet Towel Work to Prevent Chemical Warfare Agent Vapor Infiltration?

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1. INTRODUCTION

Several public information efforts in the Chemical Stockpile Emergency Preparedness Program (CSEPP) advocate the use of wet towels to (1) seal a door jam against the infiltration of chemical vapors and (2) provide expedient respiratory protection.

A wet towel has been a common respiratory protection practice for fires to reduce inhalation of soot and smoke, but will this strategy protect against chemical vapors? Using a wet towel to reduce infiltration of chemicals into a room by sealing the gap between the floor and the door is frequently cited in the shelter-in-place (SIP) literature (see Blewett et al. 1996).

The purpose of this paper is to examine the effectiveness of such measures to reduce exposure to vapors from chemical warfare agents. This evaluation includes an examination of the physical and the psychological effectiveness of these measures. Little research has been conducted to examine the effectiveness of expedient protection against chemical vapors and aerosols. More is known about the penetration of aerosols than vapor. In this paper, we summarize the research to date and offer several recommendations for CSEPP.

2. PREVIOUS RESEARCH ON EXPEDIENT PROTECTION

The first documented research on expedient respiratory protection was conducted by Guyton et. al. (1959). They performed a series of tests to determine whether common household items provided respiratory protection against a release of radiological or biological aerosols. The materials they tested included

- a man's cotton handkerchief,
- a women's cotton handkerchief,
- cotton clothing material,
- muslin bed sheet,
- cotton shirt,
- rayon slip,
- cotton terry bath towel, and
- toilet paper.

In total, 18 variations of the 8 materials were tested. The tests performed used human subjects who inhaled *B. globigii* (a bacteria aerosol) through the various materials into a mouthpiece collector. The results of the testing indicated that 5 of the variations had filtration efficiency of greater than 85%. These included a folded (16 and 8 thickness) or crumpled handkerchief, 3 thickness of toilet paper, and a bath towel folded in half. Tests

were performed on wetted items, but the efficiency was lower than for dry items. In addition, only the bath towel was feasible to breath through when wet. No testing for vapor protection was performed.

A series of experiments was performed by the Harvard School of Public Health in the early 1980's (Cooper, Hinds, and Price 1981; 1983; Cooper et al. 1983a,b; Price, Cooper, and Yee 1985). These efforts sought to build on the work of Guyten et al. by examining the penetration of expedient materials by particle size and by examining penetration by vapors. Materials similar to those in the earlier studies were used; but instead of human subjects, several test chambers were designed. Mineral oil was used for the aerosol tests and methyl iodide and iodine were used in the vapor tests. Methyl iodide is a difficult vapor to capture, while iodine, a highly reactive gas, was chosen because it is readily removed by wet filtration, thus setting the upper boundary for effectiveness against a gas.

The first set of tests examined the effectiveness of the materials in filtering the aerosols and vapors. For aerosols, the reductions by a factor of 30 were achieved with the dry materials across the range of aerosol sizes. Reductions by a factor of five were achieved with wet materials. No filtration was achieved with dry materials for both vapors. As predicted, wet materials had no effectiveness for methyl iodide but were effective in filtration of iodine vapors (60 % filtration) (Cooper, Hinds, and Price 1981; 1983).

Additional experiments were performed using a manikin to evaluate aerosol leakage around the protective materials assessed in the first experiments. These tests showed that the leakage rates around the edges of the expedient materials (in addition to the leakage of the materials), ranged as high as 63%. The study concluded that holding expedient materials over the face would not provide significant protection against aerosols due to the leakage problem. The study also concluded that some material, such as a panty hose, was needed to secure the expedient protective materials around the mouth and nose in order to minimize leakage (Cooper et al. 1983a,b). Although vapors were not included in this study, it is reasonable to assume that leakage around the perimeters of the materials would also be problematic for vapors.

Additional tests were performed with aerosols in the extremely small particle size range (Price, Cooper, and Yee 1985). These tests, as with the other aerosol tests, are not relevant for civilian protection in CSEPP SIP actions because of the extremely low likelihood of aerosol contamination off-post.

A major concern in all studies was the ability to inhale through the expedient materials. This proved problematic for all wet materials except for wet toweling. For the thick dry materials, such as the folded handkerchief—which was the most effective filter, breathing comfortably would be possible for only short periods of time.

Additional work on the effectiveness of expedient protection against chemical warfare agent simulants was conducted as part of a study on chemical protective clothing materials (Pal et al. 1993). Materials included a variety of chemical-resistant fabrics and duct tape. The materials were subject to liquid challenges by the simulants DIMP (GB

simulant), DMMP (VX simulant), MAL (organoposphorous pesticide), and DBS (mustard simulant). The study concluded that "Duct tape exhibits reasonable resistance to permeation by the 4 simulants, although its resistance to DIMP (210 min) and DMMP (210 min) is not as good as its resistance to MAL (>24 h) and DBS (> 7 h). Due to its wide availability, duct tape appears to be a useful expedient material to provide at least a temporary seal against permeation by the agents" (Pal et al. 1993, p. 140).

3. ADDITIONAL CONSIDERATIONS

Expedient respiratory protection may have social-psychological benefits as well as problems that need to be examined as well.

Problems

Expedient respiratory protection can cause or exacerbate problems by

- deterring oral communications among a family in a sheltered room and communications are very important in a SIP situation,
- deterring taping a room if people attempt to use expedient respiratory protection from the onset of SIP,
- being an additional resource for a SIP kit or materials that would need to be located at the time of a SIP warning,
- hampering driving ability during evacuation because of impairment of hand use and possible visual difficulty, and
- causing hyperventilation in some people with a tendency to be claustrophobic about impediments to breathing.

Benefits

Expedient respiratory protection can also

- have a placebo effect, making people believe they are safe while they are in a SIP and
- reinforcing the concept of proactive protection during SIP.

Overall, it appears that the non-physical benefits of expedient respiratory protection do not exceed the potential problems. However, it will be important to communicate to the public that expedient respiratory protection is beneficial in other emergency situations (such as a fire or for volcanic ash).

4. RECOMMENDATIONS FOR CSEPP

Respiratory protection for civilians has never been considered a viable option for population protection in the CSEPP. Problems of storage, ability to effectively don respirators, and questionable fit have been primary factors in rejecting this option. Expedient respiratory protection seems to offer little benefit for population protection.

Because chemical warfare agent vapors are not reactive with water—or, in some cases, not very soluble, even if easily hydrolyzed (Munro et al. 1999)—it is unlikely that wetted towels will provide significant respiratory protection while a person is sheltering in place. In no case would it be recommended that people attempt to evacuate through a vapor plume with or without expedient respiratory protection. Because of the physical ineffectiveness of the practice and the fact that the social-psychological benefits do not outweigh the social-psychological problems, we recommend that expedient respiratory protection should not be used in CSEPP protective action strategies.

Furthermore, we believe that using wet towels as a vapor barrier at the bottom of a door should be discouraged in favor of using duct tape to seal the bottom of doors. A wet towel provides no vapor filtration; and while it will reduce infiltration, its effectiveness in doing so is not known. A towel wetted with a 0.5% solution of hypochlorite (a 1:9 dilution of household bleach) may provide some protection. A hypochlorite solution is an effective decontaminant for nerve agent vapors and would provide dual protection, both physical and chemical (Munro et al. 1990). Taping the bottom of the door will still likely provide greater infiltration reduction and is recommended as the current method for use in SIP for CSEPP.

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EVALUATING PROTECTIVE ACTIONS FOR CHEMICAL AGENT EMERGENCIES

by

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Trelleborg AB 1987. *Protective Jacket (type 36)*, Manufacturer's Brochure, Trelleborg AB, Protective Products Division, S-23181, Trelleborg, Sweden.

Fig. C.2. Protective jacket and hood for children. See Trelleborg AB, *Protective Jacket (type 36)*, manufacturer's brochure, S-23181, Protective Products Division, Trelleborg, Sweden, 1987; Forsheda Group, *Forsheda, A Worldwide Group of Polymer Companies*, manufacturer's brochure, 33012, Forsheda AB, Forsheda, Sweden, 1987.

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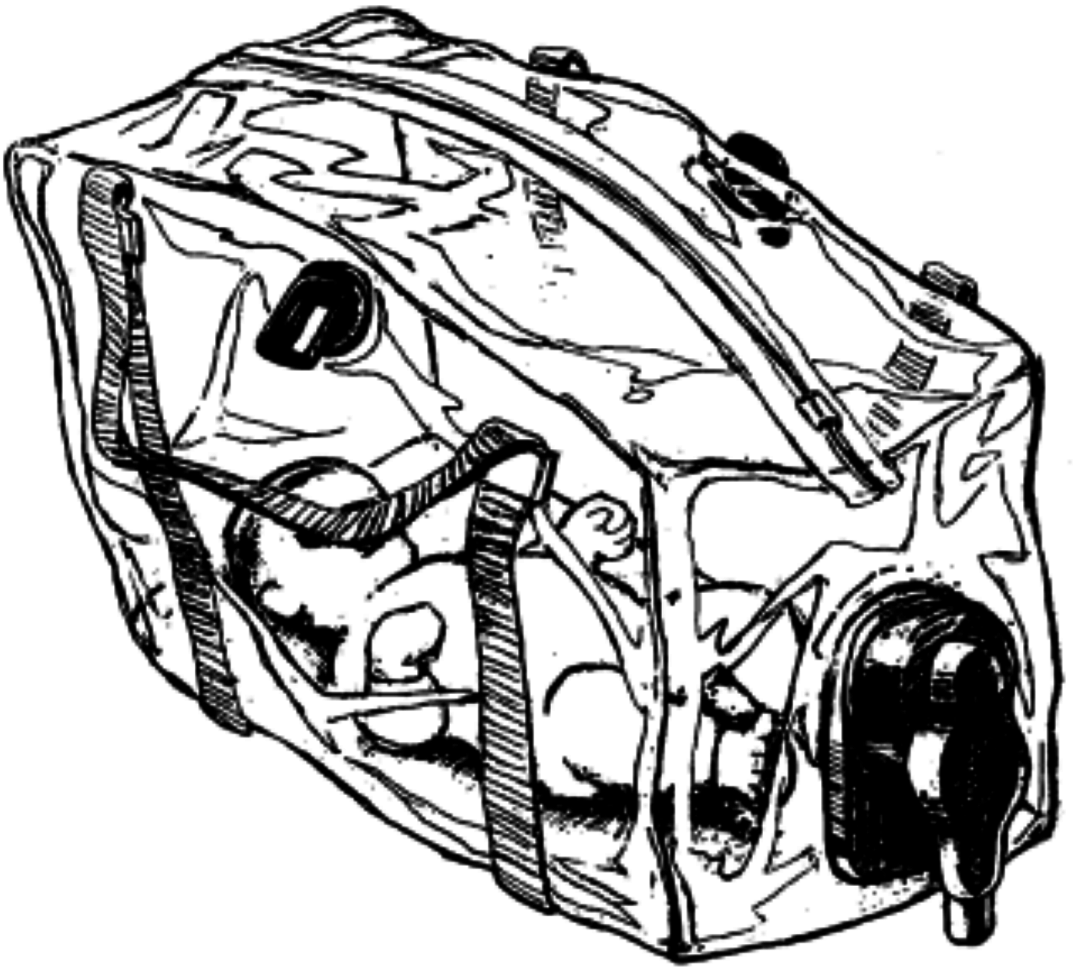

Fig. C.3. Protective bubble for infants. See Trelleborg AB, *Protective Baby-lift (type 39)*, manufacturer's brochure, S-2318, Trelleborg AB, Protective Products Division, Trelleborg, Sweden, 1987.

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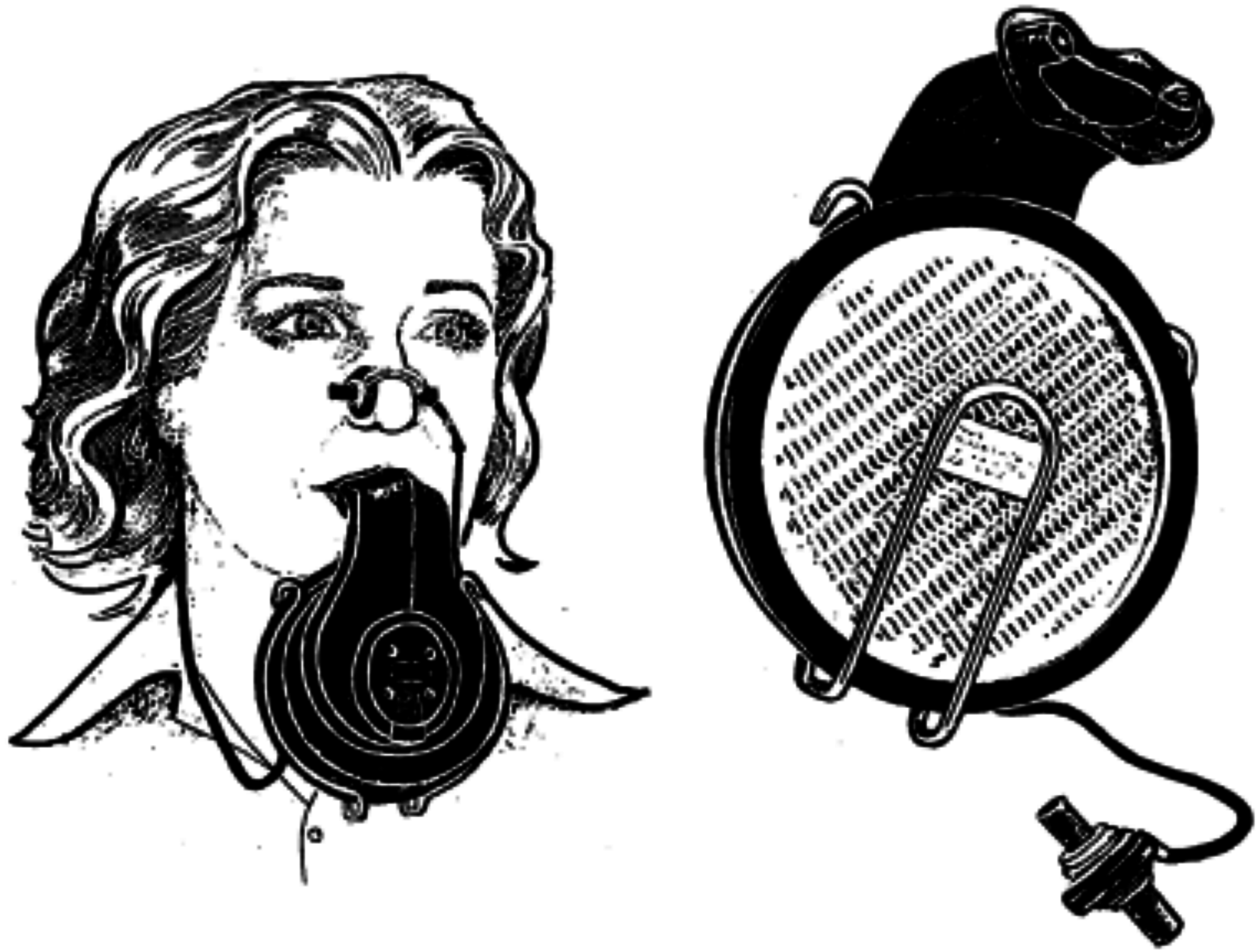


Fig. C.4. Mouthpiece respirator. See Mines Safety Appliance, *Miniguide to Safety and Health Products*, manufacturer's brochure, MSA International, Pittsburgh, 1986.

Mines Safety Appliance 1986. *Miniguide to Safety and Health Products*, Manufacturer's Brochure. MSA International, Pittsburgh, Pa.

APPENDIX G
INSTRUCTIONS FOR IMPLEMENTING EXPEDIENT SHELTER IN CHEMICAL EMERGENCIES

Entering your dwelling or other buildings and following a few simple procedures can reduce exposure to released toxic chemical. These instructions can help you implement a series of actions to increase your protection. The series includes six basic steps:

1. preparing your dwelling to provide protection,
2. selecting an appropriate room within your dwelling to provide maximum shelter,
3. assembling the necessary materials needed to complete the procedures,
4. sealing a room within the dwelling to provide additional protection,
5. remaining in the shelter until notified that the hazard has passed, and
6. vacating the shelter upon plume passage.

Because each house is in some ways unique, you may need to adapt these procedures to your particular home. These instructions order the activities in terms of what is most important in obtaining maximum protection. Therefore, we recommend that you follow these steps in sequence wherever possible. Time is critically important to ensure adequate protection, so implement each step as quickly as you can without making mistakes and continue to the next step as soon as possible.

G.1. Preparing Your Dwelling

The objective is to prepare your dwelling to provide the maximum reduction of airflow from outside to inside. These preliminary steps also provide some protection while you carry out the procedures.

1a. Go or stay indoors.
1b. Close all exterior doors and windows (close storm windows if this can be done quickly). Don't forget garage doors in integral or attached garages as well as doors normally left open for ventilation.
1c. Close all interior doors.
1d. Turn off central heat/air conditioning fans, ceiling fans, kitchen hood fans, and circulating fans.

G.2. Selecting the Appropriate Room

The objective is to select the room that is best suited to reducing overall air infiltration while <u>having at least 10 square feet of floor area per person.</u> Under hot and humid conditions more space is advisable to avoid conditions that might lead to heat prostration within the shelter. Moreover, room air conditioners that recirculate internal

air may be used to create more comfortable shelter conditions. For example a 5×8 foot room has 40 ft^2, which would be appropriate for sheltering up to 4 people. This step can be completed in advance. If you have already preselected the room to provide maximum shelter, skip to Sect. G.3 below.

2a. The best room is a relatively small, has no outside walls, and is on the ground floor.
2b. If 2a is not available; select a small room with no windows.
2c. If 2a and 2b are not available: select the room with the smallest number of windows and doors.
2d. Avoid rooms with window air conditioners, windows that leak, vents to outside such as automatic dryer vents, and circulation vents.
2e. <u>Do not select rooms with exhaust vents that automatically start when the light is turned on</u>. These exhaust fans force external air into the room.
2f. If all the above elements are the same for two rooms, choose the room that is free of plumbing fixtures, because such fixtures increase the potential airflow and will require sealing as described in Sect. G.4 below.

G.3. Assembling Materials and Resources

This stage of the procedures is designed to collect all the needed materials to reduce the airflow as much as possible in the room you selected in Sect. G.2 above. This step can be performed ahead of time. Place the following materials in the selected room.

3a. the expedient shelter kit provided;
3b. verify that the kit still has the tape, plastic sheet, scissors, clay, and screwdriver;
3c. obtain a large towel (at least bath-towel size);
3d. a ladder, stool, or chair if required to seal any ceiling vents or the tops of windows and doors;
3e. a radio or television or other communication device (preferably portable) to let you to know when the plume has passed so you can exit at an appropriate time; and
3f. if the selected room does not have plumbing, drinking water and sanitary facilities (a covered bucket or other vessel containing approximately 1 cup of chlorine bleach).

G.4. Taping and Sealing

This set of procedures is designed to identify and seal the major sources of airflow between the room you have selected and the rest of the house, as well as restrict the flow of any toxic chemical that may be outside. These steps are sequenced to eliminate larger sources of air exchange first, so they should be implemented in the order listed whenever possible.

4a. Assemble people to be protected in the selected room and close the door. If windows were not closed as instructed in Sect. G.1 above, do so now.

4b. Jam the towel under the entire width of the door, sealing the whole area between the bottom of the door and the floor.

4c. VENTS: <u>If there are no vents, skip to step 4d below</u>. Locate any vents associated with the heating system, fan vents which are sometimes located in bathrooms, or vents to other rooms or to the outside such as dryer vents. Then, tape over small vents repeatedly, overlapping the tape to form a complete seal. For large vents, cut a piece of plastic sheeting large enough to cover the vent, place it over the vent, and tape the plastic loosely in place at the corners. Tape the plastic along each edge to ensure a complete seal. Repeat for each vent in the room.

4d. WINDOWS: <u>If there are no windows, skip to step 4e below</u>. If there are any broken or cracked windows, apply tape or cling-wrap over glass. Locate all leak points (any joints in the window frame, where movable parts of the frame come together), apply cling-wrap to each leak point. Then, cut a piece of plastic sheeting large enough to cover window and window frame, place it over the window and frame, and tape the plastic loosely in place at the corners. Tape the plastic along each edge to ensure a complete seal.

4e. Before you complete the seal on the door, check all supplies to ensure that you have enough material to completely seal the door. <u>Do not open the door unless you clearly have inadequate materials to complete the seal</u>; breaking the door seal will substantially reduce the protection provided by the refuge.

4f. DOOR: Tape along each edge of the door to seal off airflow, beginning with the parts you can reach from the floor and proceeding to the upper parts that may require the use of a ladder, stool, or chair. Place and tape cling-wrap over each hinge and the door handle.

4g. PLUMBING FIXTURES: <u>If there are no plumbing fixtures, skip to step 4h below</u>. Use putty or clay around all pipes that penetrate walls, ceiling, or floor (both intake and drainage pipes). To apply clay or putty, pull back the pipes decorative sealing ring (use screwdriver if necessary), wrap enough clay or putty around the pipe to fill any gaps between the wall and the pipe, and reset the decorative ring in clay by pressing the ring firmly against wall. Repeat for all pipe entry and exit points.

4h. CABINETS: <u>If there are no built-in cabinets such as sink cabinets, linen closets, or medicine cabinets, skip to step 4i below</u>. Close the cabinet doors and tape them closed according to the procedures described for doors in step 4f above. Note that, because cabinet hinges and handles are smaller than those on doors, tape will probably cover these areas adequately. Then, tape or use cling-wrap along all joints where the cabinet meets the wall. Pay particular attention to kickplates below cabinets, by checking the underside for holes and gaps. Smaller gaps may need to be plugged with clay.

4i. ELECTRICAL FIXTURES: Locate all electrical fixtures, including outlets, switch boxes, and lights. If a light is recessed or if it cannot be sealed without

turning it off, it will have to remain unsealed because covering a light without turning it off may start a fire. Put tape over the outlet boxes, and use cling-wrap or tape to cover all switch boxes. Put cling-wrap over light fixtures not in use. (Some light fixtures contain fans that run continuously with the light in the room. These fans should be turned off as early as practical; if they cannot be turned off, a different room should be selected as instructed in Sect. G.2 above.)

4j. CHECKING YOUR WORK: After, you have completed the procedures to seal the room you have selected, check each area you sealed by slowly passing your hand in front of all potential leak areas. If you can feel air flowing, try to seal it better. We do not recommend that you remove any previous seals, but you may want to add plastic sheeting over sealed areas or tape them more securely.

G.5. Remaining in Shelter

The objective of this stage is to relax as much as possible and wait to be notified of the appropriate time to exit the shelter.

5a. Shelter occupants should be as comfortable as possible; they should stand or move around as little as possible.
5b. Remain calm and relax; doing so adds additional protection by reducing your respiration rate.
5c. Turn on communication device so you can be contacted when it is safe to exit the shelter.
5d. Ask each occupant to periodically check for airflows near them. If any are discovered, seal them by following the above procedures.
5e. Wait for notification of plume passage.

G.6. Vacate Shelter

The objective of this step is to exit the shelter when the plume passes by and to avoid any further cumulative exposure.

6a. Put on protective clothing.
6b. Open all windows and doors.
6c. Evacuate to reception center for medical evaluation and decontamination.

EXPEDIENT SHELTER INSTRUCTION CHECKLIST

1. Prepare your dwelling to provide protection.

1a. Go or stay indoors.
1b. Close all exterior doors and windows.
1c. Close all interior doors.
1d. Turn off fans.

2. Select an appropriate room within your dwelling to provide maximum shelter, <u>having at least 10 square feet of floor area per person</u>.

2a. Choose a relatively small room with no outside walls on the ground floor.
2b. If not available: select a small room with no windows.
2c. If not available: select the room with the fewest windows and doors.
2d. Avoid rooms with window air conditioners, windows that leak, vents to the outside, and circulation vents whenever possible.
2e. Avoid rooms with plumbing fixtures whenever possible.

3. Assemble the necessary materials.

3a. Use the expedient shelter kit provided;
3b. Verify that its contents are complete;
3c. Large towel of at least bath-towel size;
3d. Ladder, stool, or chair if necessary;
3e. Radio, television, or other communication device;
3f. Drinking water and covered container with chlorine bleach for sanitary purposes.

4. Seal a room in the dwelling to provide additional protection.

4a. Enter the selected room and close the door.
4b. Jam the towel under the door.
4c. Seal vents.
4d. Seal windows.
4e. Check all supplies; replace if necessary.
4f. Seal door.
4g. Seal plumbing.
4h. Seal cabinets.
4i. Seal electrical fixtures.
4j. Check you work; reseal where necessary.

5. Remain in the shelter until notified that the plume has passed.

- 5a. Get as comfortable as possible.
- 5b. Remain calm, relax, and stay immobile.
- 5c. Turn on communication device.
- 5d. Periodically check for airflows in the shelter.
- 5e. Wait for notification of plume passage.

6. Vacate shelter.

- 6a. Don protective clothing.
- 6b. Open all windows and doors.
- 6c. Evacuate.

POTENTIAL MILITARY CHEMICAL/BIOLOGICAL AGENTS AND COMPOUNDS, US Army FM 3-11.9, 2005

Table G-4. Toxicity Estimates for CW Agents

ROE		Liquid (mg/70 kg man)		Inhalation/Ocular (mg-min/m^3)			Inhalation (mg/m^3)	Ocular (mg-min/m^3)		Percutaneous Vapor (mg-min/m^3)			
Endpoints		Lethal (LD_{50})	Severe (ED_{50})	Lethal (LCt_{50})	Severe (ECt_{50})	Mild (ECt_{50})	Odor Detection (EC_{50})	Severe (ECt_{50})	Mild (ECt_{50})	Lethal (LCt_{50})		Severe (ECt_{50})	
										Moderate	Hot	Moderate	Hot
Choking Agents	CG	-	-	1,500 (2-60)	-	-	6 S	-	-	-	-	-	-
	DP	-	-	1,500P (10-60)	-	-	4 S	-	-	-	-	-	-
Nerve Agents	GA	1,500	900	70 (2)	50 (2)	0.4 (2)	-	-	-	15,000 (30-360)	7,500P (30-360)	12,000 (30-360)	6,000P (30-360)
	GB	1,700	1,000	35 (2)	25 (2)	0.4 (2)	-	-	-	12,000 (30-360)	6,000P (30-360)	8,000 (30-360)	4,000P (30-360)
	GD	350	200	35 (2)	25 (2)	0.2 (2)	-	-	-	3,000 (30-360)	1,500P (30-360)	2,000 (30-360)	1,000P (30-360)
	GF	350	200	35 (2)	25 (2)	0.2 (2)	-	-	-	3,000 (30-360)	1,500P (30-360)	2,000 (30-360)	1,000P (30-360)
	VX	5	2	15 (2-360)	10 (2-360)	0.1 (2-360)	-	-	-	150 (30-360)	75P (30-360)	25 (30-360)	12P (30-360)
	Vx	NR											
Blood Agent	AC	-	-	2860P (2)	NR		34 S	-	-	-	-	-	-
	CK	-	-	NR	NR		12 S	-	-	-	-	-	-
	SA	-	-	7,500P (2)	-	-	-	-	-	-	-	-	-
Blister Agents	HD	1400	600	1,000 (2)	-	-	0.6 – 1 S	75 (2-360)	25 (2-360)	10,000 (30-360)	5,000P (30-360)	500 (30-360)	200 (30-360)
	HN-1	1400P	600P	1,000P (2)	-	-	-	75P (2)	25P (2)	10,000P (30)	5,000P (30)	500P (30)	200P (30)
	HN-2	1400P	600P	1,000P (2)	-	-	-	75P (2)	25P (2)	10,000P (30)	5,000P (30)	500P (30-360)	200P (30-360)
	HN-3	1400P	600P	1,000P (2-360)	-	-	-	75P (2-360)	25P (2-360)	10,000P (30-360)	5,000P (30-360)	500P (30-360)	200P (30-360)
	HT	1400P	600P	1,000P (2-360)	-	-	-	75P (2-360)	25P (2-360)	10,000P (30-360)	5,000P (30-360)	500P (30-360)	200P (30-360)
	L	1400P	600P	1,000P (2-360)	-	-	8 S	75P (2-360)	25P (2-360)	5,000 - 10,000P (30-360)	2,500 - 5,000P (30-360)	500P (30-360)	200P (30-360)
	HL	1400P	600P	1,000P (2-360)	-	-	2 S	75P (2-360)	25P (2-360)	10,000P (30-360)	5,000P (30-360)	500P (30-360)	200P (30-360)

COMPARATIVE VOLATILITY OF CHEMICAL WARFARE AGENTS

Agent	Volatility (mg/m^3) at 25°C
Hydrogen cyanide (HCN)	1,000,000
Sarin (GB)	22,000
Soman (GD)	3,900
Sulfur mustard	900
Tabun (GA)	610
Cyclosarin (GF)	580
VX	10
VR ("Russian VX")	9

Data source: US Departments of the Army, Navy, and Air Force. *Potential Military Chemical/Biological Agents and Compounds*. Washington, DC: Headquarters, DA, DN, DAF; December 12, 1990. Field Manual 3-9. Naval Facility Command P-467. Air Force Regulation 355-7.

SIGNS AND SYMPTOMS REPORTED BY TOKYO HOSPITAL WORKERS TREATING VICTIMS OF SARIN SUBWAY ATTACKS*

Symptom	Number/percentage of the 15 physicians who treated patients at UH		Number/percentage of 472 care providers reporting symptoms at SLI	
Dim vision	11	73%	66	14%
Rhinorrhea	8	53%	No information	
Dyspnea (chest tightness)	4	27%	25	5.3%
Cough	2	13%	No information	
Headache	No information		52	11%
Throat pain	No information		39	8.3%
Nausea	No information		14	3.0%
Dizziness	No information		12	2.5%
Nose pain	No information		6	1.9%

*Data reflect reported survey of self-reported symptomatology of physicians at the University Hospital of Metropolitan Japan emergency department and all hospital workers at Saint Luke's International Hospital exposed to sarin vapors from victims of the Tokyo subway attack.

SLI: Saint Luke's International Hospital

UH: University Hospital

Data sources: (1) Nozaki H, Hori S, Shinozawa Y, et al. Secondary exposure of medical staff to sarin vapor in the emergency room. *Intensive Care Med*. 1995;21:1032-1035. (2) Okumura T, Suzuki K, Fukuda A, et al. The Tokyo subway sarin attack: disaster management, Part 1: community emergency response. *Acad Emerg Med*. 1998;5:613-617. (3) Okumura T, Suzuki K, Fukuda A, et al. The Tokyo subway sarin attack: disaster management, Part 2: Hospital response. *Acad Emerg Med*. 1998;5:618-624.

TABLE 21-3

MANAGEMENT OF MILD TO MODERATE NERVE AGENT EXPOSURES

		Management			
		Antidotes*		Benzodiazepines (if neurological signs)	
Nerve Agents	**Symptoms**	**Age**	**Dose**	**Age**	**Dose**
• Tabun • Sarin • Cyclosarin • Soman • VX	• Localized sweating • Muscle fasciculations • Nausea • Vomiting • Weakness/floppiness • Dyspnea • Constricted pupils and blurred vision • Rhinorrhea • Excessive tears • Excessive salivation • Chest tightness • Stomach cramps • Tachycardia or bradycardia	Neonates and infants up to 6 months old	**Atropine** 0.05 mg/kg IM/IV/IO to max 4 mg or 0.25 mg AtroPen† and **2-PAM** 15 mg/kg IM or IV slowly to max 2 g/hr	Neonates	**Diazepam** 0.1–0.3 mg/kg/dose IV to a max dose of 2 mg, or **Lorazepam** 0.05 mg/kg slow IV
		Young children (6 months old–4 yrs old)	**Atropine** 0.05 mg/kg IM/IV/IO to max 4 mg or 0.5 mg AtroPen and **2-PAM** 25 mg/kg IM or IV slowly to max 2 g/hr	Young children (30 days old–5 yrs old)	**Diazepam** 0.05–0.3 mg/kg IV to a max of 5 mg/dose or **Lorazepam** 0.1 mg/kg slow IV not to exceed 4 mg
		Older children (4–10 yrs old)	**Atropine** 0.05 mg/kg IV/IM/IO to max 4 mg or 1 mg AtroPen and **2-PAM** 25–50 mg/kg IM or IV slowly to max 2 g/hr	Children (≥ 5 yrs old)	**Diazepam** 0.05–0.3 mg/kg IV to a max of 10 mg/dose or **Lorazepam** 0.1 mg/kg slow IV not to exceed 4 mg
		Adolescents (≥ 10 yrs old) and adults	**Atropine** 0.05 mg/kg IV/IM/IO to max 4 mg or 2 mg AtroPen and **2-PAM** 25–50 mg/kg IM or IV slowly to max 2 g/hr	Adolescents and adults	**Diazepam** 5–10 mg up to 30 mg in 8 hr period or **Lorazepam** 0.07 mg/kg slow IV not to exceed 4 mg

2-PAM: 2-pralidoxime
IM: intramuscular
IO: intraosseous
IV: intraveneous
PDH: Pediatrics Dosage Handbook
*In general, pralidoxime should be administered as soon as possible, no longer than 36 hours after the termination of exposure. Pralidoxime can be diluted to 300 mg/mL for ease of intramuscular administration. Maintenance infusion of 2-PAM at 10–20 mg/kg/hr (max 2 g/hr) has been described. Repeat atropine as needed every 5–10 minutes until pulmonary resistance improves, secretions resolve, or dyspnea decreases in a conscious patient. Hypoxia must be corrected as soon as possible.
†Meridian Medical Technologies Inc, Bristol, Tenn.
Data sources: (1) Rotenberg JS, Newmark J. Nerve agent attacks on children: diagnosis and management. *Pediatrics*. 2003;112:648–658. (2) Pralidoxime [package insert]. Bristol, Tenn: Meridian Medical Technologies, Inc; 2002. (3) AtropPen (atropine autoinjector) [package insert]. Bristol, Tenn: Meridian Medical Technologies, Inc; 2004. (4) Henretig FM, Cieslak TJ, Eitzen Jr EM. Medical progress: biological and chemical terrorism. *J Pediatr*. 2002;141(3):311–326. (5) Taketomo CK, Hodding JH, Kraus DM. *American Pharmacists Association: Pediatric Dosage Handbook*. 13th ed. Hudson, Ohio; Lexi-Comp Inc: 2006.

TABLE 21-4

MANAGEMENT OF SEVERE NERVE AGENT EXPOSURE

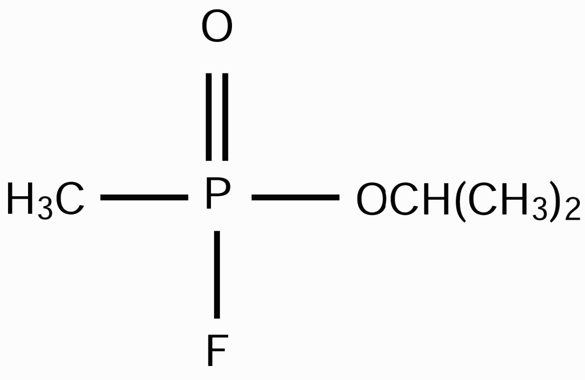
		Management			
		Antidotes*		Benzodiazepines (if neurological signs)	
Nerve Agents	**Severe Symptoms**	**Age**	**Dose**	**Age**	**Dose**
• Tabun • Sarin • Cyclosarin • Soman • VX	• Convulsions • Loss of consciousness • Apnea • Flaccid paralysis • Cardio-pulmonary arrest • Strange and confused behavior • Severe difficulty breathing • Involuntary urination and defecation	Neonates and infants up to 6 months old	**Atropine** 0.1 mg/kg IM/IV/IO or 3 doses of 0.25mg AtroPen† (administer in rapid succession) and **2-PAM** 25 mg/kg IM or IV slowly, or 1 Mark I† kit (atropine and 2-PAM) if no other options exist	Neonates	**Diazepam** 0.1–0.3 mg/kg/dose IV to a max dose of 2 mg, or **Lorazepam** 0.05 mg/kg slow IV
				Young children (30 days old–5 yrs and adults	**Diazepam** 0.05–0.3 mg/kg IV to a max of 5 mg/dose, or **Lorazepam** 0.1 mg/kg slow IV not to exceed 4 mg
		Young children (6 months old–4 yrs old)	**Atropine** 0.1 mg/kg IV/IM/IO or 3 doses of 0.5mg AtroPen (administer in rapid succession) and **2-PAM** 25–50 mg/kg IM or IV slowly, or 1 Mark I kit (atropine and 2-PAM) if no other options exist	Children (≥ 5 yrs old)	**Diazepam** 0.05-0.3 mg/kg IV to a max of 10 mg/dose, or **Lorazepam** 0.1 mg/kg slow IV not to exceed 4 mg
				Adolescents and adults	**Diazepam** 5–10 mg up to 30 mg in 8-hr period, or **Lorazepam** 0.07 mg/kg slow IV not to exceed 4 mg
		Older children (4–10 yrs old)	**Atropine** 0.1 mg/kg IV/IM/IO or 3 doses of 1mg AtroPen (administer in rapid succession) and **2-PAM** 25–50 mg/kg IM or IV slowly, 1 Mark I kit (atropine and 2-PAM) up to age 7, 2 Mark I kits for ages > 7–10 yrs		
		Adolescents (≥ 10 yrs old) and adults	**Atropine** 6 mg IM or 3 doses of 2 mg AtroPen (administer in rapid succession) and **2-PAM** 1800 mg IV/IM/IO, or 2 Mark I kits (atropine and 2-PAM) up to age 14, 3 Mark I kits for ages ≥ 14 yrs		

IM: intramuscular
IO: intraosseous
IV: intravenous

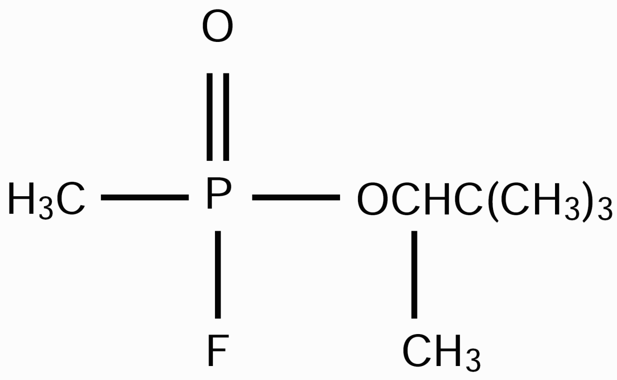
*In general, pralidoxime should be administered as soon as possible, no longer than 36 hours after the termination of exposure. Pralidoxime can be diluted to 300 mg/mL for ease of intramuscular administration. Maintenance infusion of 2-PAM at 10–20 mg/kg/hr (max 2 g/hr) has been described. Repeat atropine as needed every 5–10 min until pulmonary resistance improves, secretions resolve, or dyspnea decreases in a conscious patient. Hypoxia must be corrected as soon as possible. †Meridian Medical Technologies Inc, Bristol, Tenn.

Data sources: (1) Rotenberg JS, Newmark J. Nerve agent attacks on children: diagnosis and management. *Pediatrics*. 2003;112:648–658. (2) Pralidoxime [package insert]. Bristol, Tenn: Meridian Medical Technologies, Inc; 2002. (3) AtroPen (atropine autoinjector) [package insert]. Bristol, Tenn: Meridian Medical Technologies, Inc; 2004. (4) Henretig FM, Cieslak TJ, Eitzen Jr EM. Medical progress: biological and chemical terrorism. *J Pediatr*. 2002;141(3):311–326. (5) Taketomo CK, Hodding JH, Kraus DM. *American Pharmacists Association: Pediatric Dosage Handbook*. 13th ed. Hudson, Ohio: Lexi-Comp Inc; 2006.

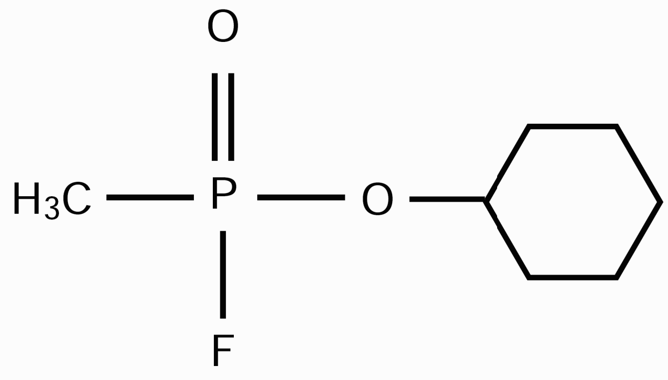
Sarin (GB)



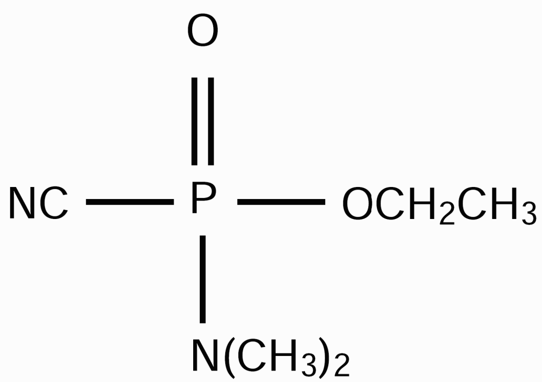
Soman (GD)



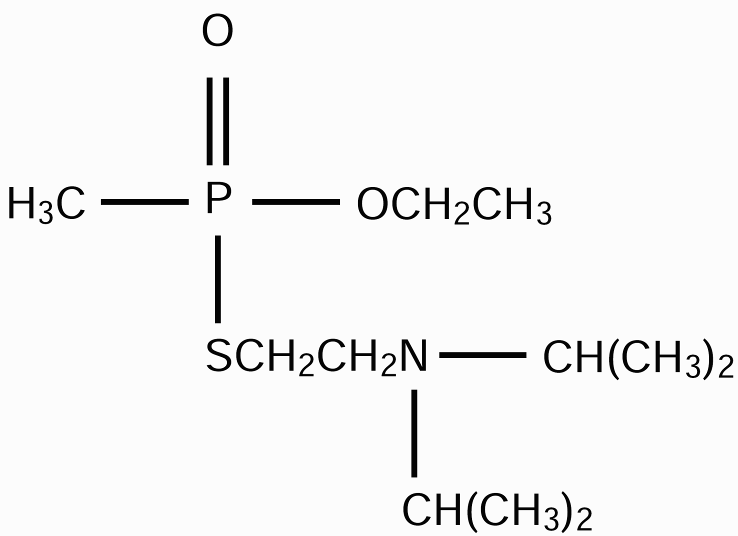
Cyclosarin (GF)



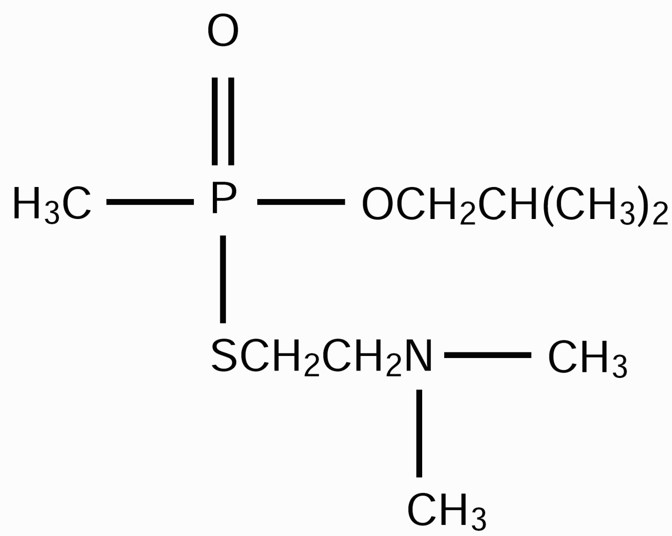
Tabun (GA)



VX



Russian VX



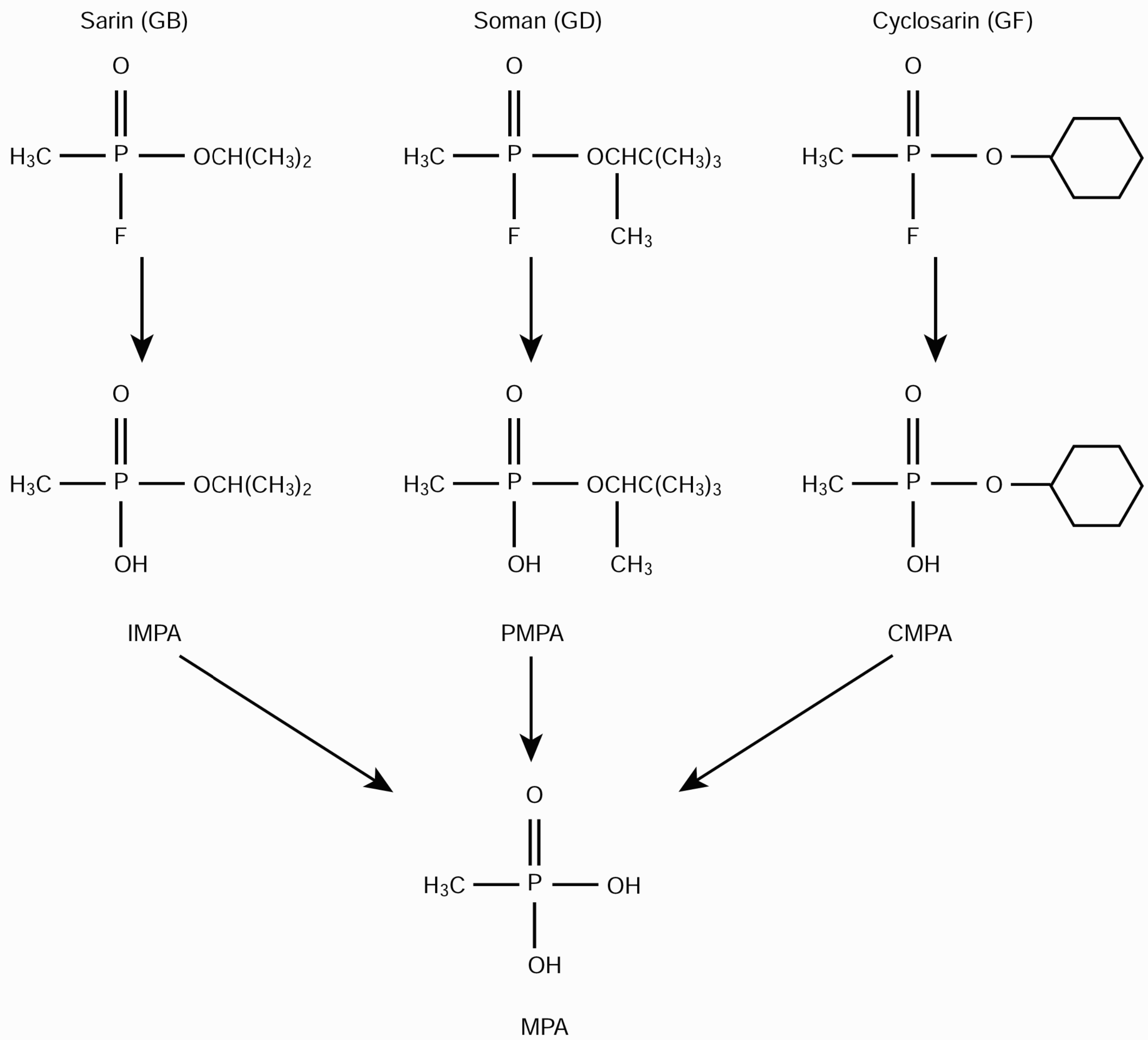


Fig. 22-2. Hydrolysis pathway of sarin (GB), soman (GD), and cyclosarin (GF). Hydrolysis pathway of nerve agents proceeds through the alkyl methylphosphonic acids IMPA, PMPA, and CMPA to MPA. Analysis of the alkyl methylphosphonic acids allows identification of the parent agent, while assay of MPA is nonspecific.
CMPA: cyclohexyl methylphosphonic acid
IMPA: isopropyl methylphosphonic acid
MPA: methylphosphonic acid
PMPA: pinacolyl methylphosphonic acid

TECHNICAL MANUAL No. 3-400
TECHNICAL ORDER No. 11C2-1-1

DEPARTMENTS OF THE ARMY AND THE AIR FORCE
WASHINGTON 25, D. C., *8 May 1957*

CHEMICAL BOMBS AND CLUSTERS

* This manual supersedes TM 3-400, 28 April 1953.

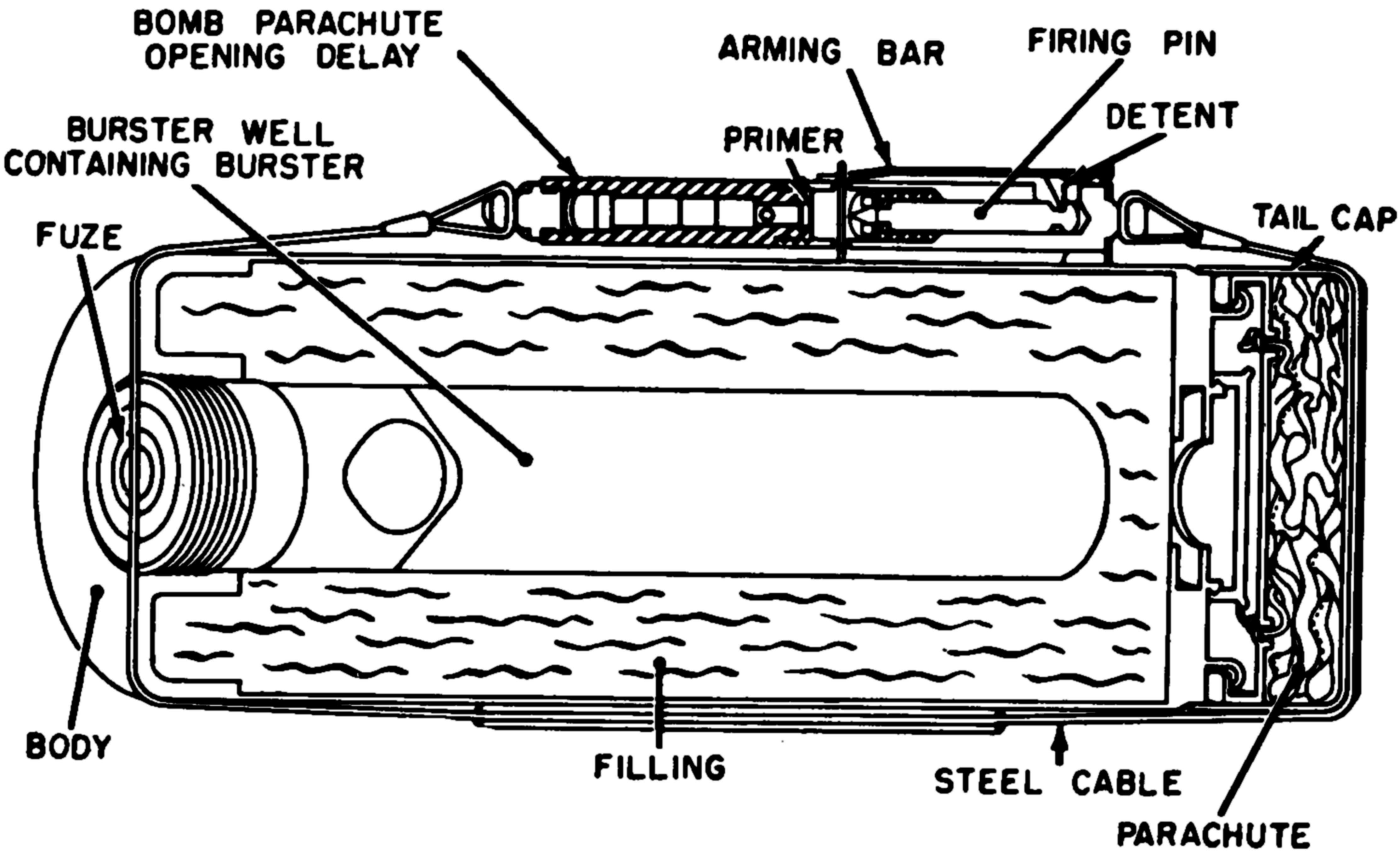


Figure 24. M125A1 10-pound GB nonpersistent gas bomb, sectional view.

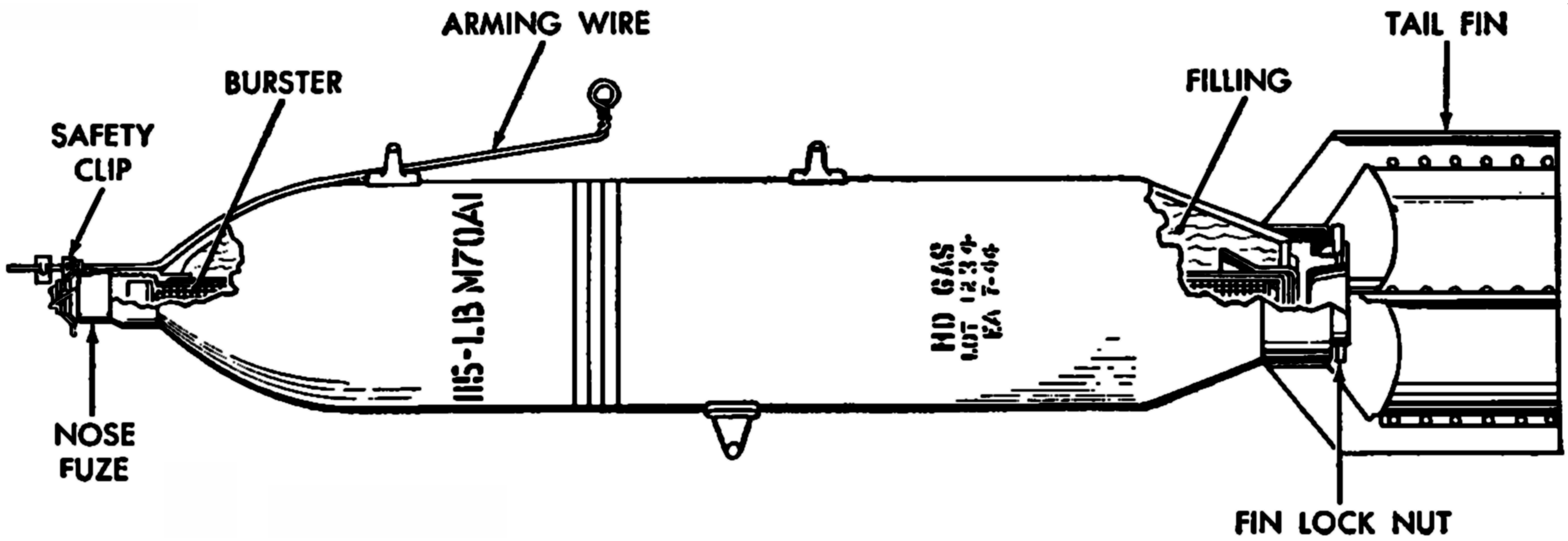


Figure 26. M70A1 115-pound HD persistent gas bomb, cutaway view.

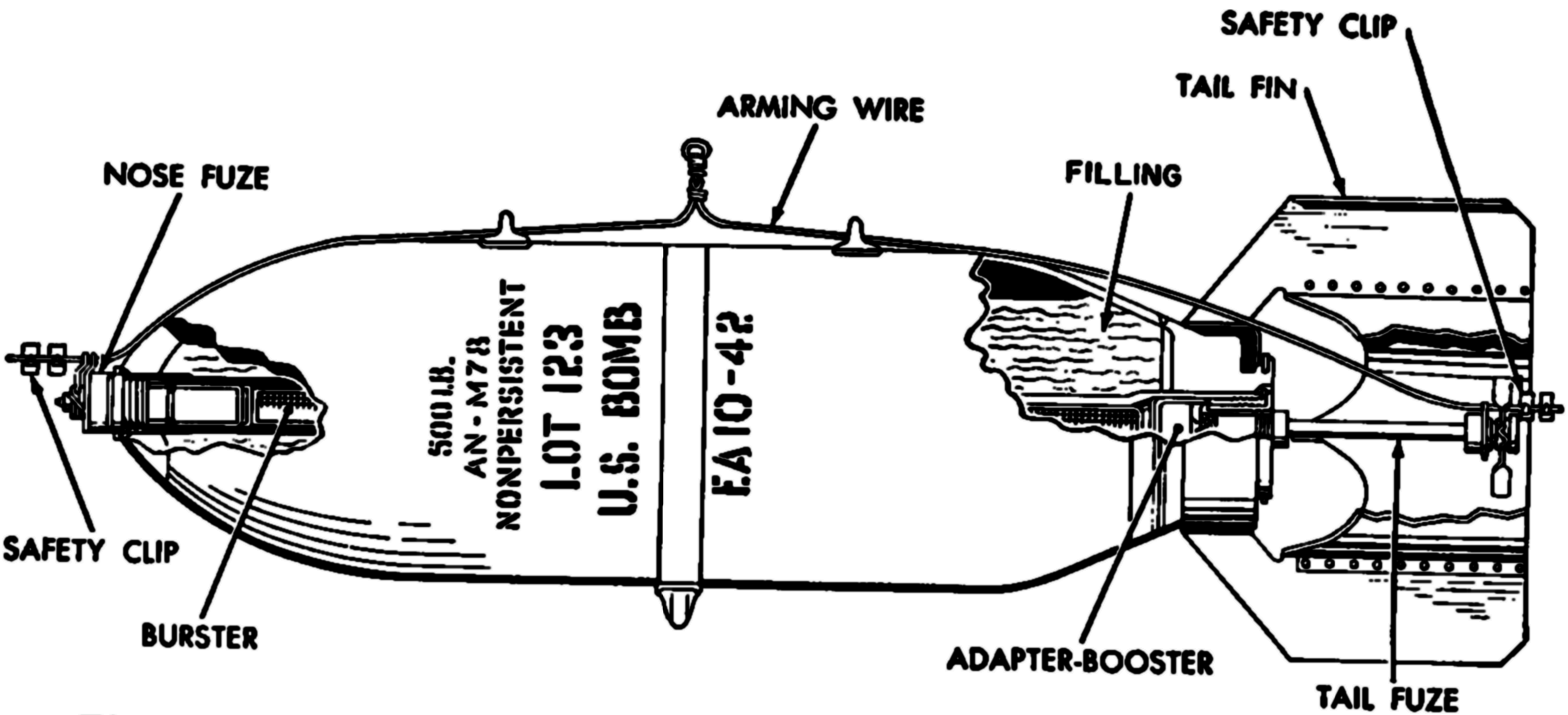


Figure 28. AN–M78 500-pound CG or CK nonpersistent gas bomb, cutaway view.

M139 (E130R2) bomblet.

The 762-millimeter M190 Honest John GB warhead. Developed as the E19R2, it carried 356 115-millimeter M134 (E130R1) spherical bomblets. The overall fill efficiency of the M190 was 37%. Range 8.5-33.8 km, bomblets released at 5 kft altitude to give a 1 km diameter area coverage.

Reid Kirby, "The CB Battlefield Legacy", Army Chemical Review, July–December 2006, pp. 25-29.

It may be several weeks or even months before I shall ask you to drench Germany with poison gas, and if we do it, let us do it one hundred per cent. In the meanwhile, I want the matter to be studied in cold blood by sensible people and not by that particular set of psalm-singing uninformed defeatists which one runs across now here, now there (Churchill 1944).

Gilbert M (1991). *Churchill. A Life*, pp. 782–783. London: Heinemann.